THE POWER HANDBOOKS

OIL FUEL

FOR

STEAM BOILERS

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BY

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PREFACE

The purpose of this volume is to describe, in clear and simple language, the principles that underlie the use of oil as a fuel in steam-boiler practice; the form and action of various types of burners; the arrangement of furnaces for burning oil under different kinds of boilers; the operation of such accessories as pumps, heaters, and cleaning devices; the methods of storing oil; and such other matters as might naturally arise in connection with the purchase and use of oil fuel.

No attempt has been made to describe the use of oil in locomotive or marine practice, or in heating, tempering and hardening furnaces, because these applications are so extensive as to deserve individual treatment. Instead, this volume is confined to the burning of oil in the furnaces of stationary steam boilers, and the endeavor has been to cover the ground fully and thoroughly.

No claim for originality is made, except in the manner of arranging and presenting the facts. The material is a compilation of the available information on the subject of oil burning, and was obtained from catalogs and from various technical publications issued during the past ten years. The greater part of the contents of this volume appeared as a series of articles in the *Electrical World* during 1913 and 1914.

The author takes this opportunity to thank the various manufacturers who furnished catalogs and other valuable information and to acknowledge his indebtedness to the publishers of the *Electrical World* for granting permission to reprint the series of articles in book form.

RUFUS T. STROHM.

SCRANTON, PA.,
May, 1914.

CONTENTS

ILLUSTRATIONS

OIL FUEL FOR STEAM BOILERS

CHAPTER I

Properties of Oil Fuel

At the rate at which oil fuel is being produced at the present time, there is no danger that it will supplant coal as a boiler fuel, except in a few localities. For if all the oil produced throughout the world in a year were used for the purpose of steam generation, it would furnish an amount of power equal to only about one-thirtieth of that annually required by the power and manufacturing plants of the globe. Therefore, unless far greater oil fields are discovered and the yearly yield of the wells is enormously increased, there is no danger that oil will become a general competitor of solid fuel in steam-boiler plants.

Nevertheless, there are localities in which oil forms a useful, economical and desirable fuel, and in which it is used to the exclusion of coal. Such localities are the regions in which the oil is produced. Yet there are oil fields in which little oil is used for steam-boiler fuel, because of the fact that the oil is more valuable for other purposes. Consequently, the factors that determine whether oil shall be used for fuel in preference to coal are as follows:

The price of the oil must be low enough to enable it to compete with coal in that particular neighborhood; the supply must be continuous and ample, so as to prevent shut-downs; and it must be of a quality that can be used without unusual difficulties in the furnace.

In the United States the greatest oil fields are located in three regions. The first of these embraces western Pennsylvania, Ohio and West Virginia. The second includes portions of Texas, Louisiana and Oklahoma. The third is in southern California. The oil that is produced in the first of these regions, however, is not used to any great extent as a fuel for steam boilers, for the simple reason that it is of such quality and composition that it is more valuable for refining. Also, this same region contains great deposits of bituminous coal, so that it is more economical to use this solid fuel for power plants.

The oil produced in the second and third fields named above is also used in refineries, but a moderate proportion is employed for fuel in boiler furnaces. The reason lies in the fact that coal is scarce in either of these fields. That is, all coal used in these districts must be brought by rail or water from some distant point or points, with the natural result that the cost per ton is greatly increased. Because of this fact, it is far cheaper to use oil as the fuel, as it is found in the immediate vicinity and does not need to be transported over such great distances.

The oils that are used for fuel are forms of petroleum, which is the term that includes all the mineral oils derived from the earth. The characteristics of petroleum, such as color, density and odor, vary according to the region

in which the oil is obtained. In some parts of the world petroleum is clear and without color, like water, and in other parts of the world it is black. The petroleum found in the United States is brown or reddish brown in color, as a rule, when in a tank or other vessel. But if a sample is poured into a glass or a bottle and is then held up so that the light can pass through it, the oil will appear to have a dark green color.

In spite of the differences in color and other characteristics, however, all petroleums are very much alike in composition; that is, they are all liquid hydrocarbons. The principal elements of which they are composed, and which make them valuable as fuel, are about the same as those in coal, namely, carbon and hydrogen; also, like coal, petroleum contains oxygen, nitrogen and moisture. The relative percentages of these constituents vary somewhat according to the locality from which the oil is derived. For example, an average Texas petroleum has 84.6 per cent. of carbon, 10.9 per cent. of hydrogen, 1.6 per cent. of sulphur and 2.9 per cent. of oxygen. A sample of California petroleum, on the other hand, contains 85 per cent. of carbon, 12 per cent. of hydrogen, 0.8 per cent. of sulphur, 1 per cent. of oxygen, 0.2 per cent. of nitrogen and 1 per cent. of moisture. Thus, petroleum may be taken as having from 83 to 87 per cent. of carbon, from 10 to 16 per cent. of hydrogen, and trifling percentages of sulphur, oxygen and nitrogen. Those oils that contain sulphur usually have a disagreeable smell, due to the presence of the sulphur.

Although all oil used for fuel is derived primarily from petroleum, it may be obtained commercially in either of

two forms, namely, crude oil and fuel oil. Crude oil is simply raw petroleum, in the condition in which it is obtained from the oil well, and is not subjected to any treatment. Fuel oil, on the other hand, is a residue; that is, it is the oil that remains when petroleum is subjected to a partial distillation.

The distillation process just referred to drives off the lighter oils contained in petroleum and leaves the heavier ones. The crude oil is put in closed tanks called stills and is slowly heated. Now, the crude oil consists of a mixture of a large number of liquid hydrocarbons having different densities and boiling points. Consequently, as the temperature in the still rises, these various oils are brought to the boiling point, one after another, and escape from the still in the form of vapor. The vapor is led through pipe coils and is chilled, whereupon it condenses and becomes liquid again.

At first, while the temperature rises from about 100 deg. Fahr. to 160 deg. Fahr., petroleum ether will be boiled off, this being a very light oil. From a temperature of 160 deg. Fahr. to about 175 deg. Fahr. gasoline will be distilled. Naphtha will be driven off while the temperature changes from about 175 deg. Fahr. to about 300 deg. Fahr., and from 300 deg. Fahr. to 570 deg. Fahr. the oil driven off will be what is commercially known as kerosene. The oil that remains in the still after the temperature has reached 570 deg. Fahr. consists of lubricating oils, paraffin and coke or asphalt. The crude oils found in the region of western Pennsylvania have a coke base, whereas those from Texas and California have an asphalt base.

The residue, or oil remaining in the still after the petroleum ether, gasoline, benzine and kerosene have been distilled, is what is frequently used as fuel for steam boilers and sold under the name of fuel oil. It is simply the oil remaining after the lighter oils have been driven off from the crude petroleum. The effect of the heating and driving off of the lighter constituents is to leave a residue that weighs more per cubic foot than the original petroleum; in other words, the density of fuel oil is greater than that of the crude oil from which it is obtained. Moreover, the distilling process causes a change in the composition of the oil. The percentages of carbon and sulphur are decreased slightly and those of hydrogen and oxygen are increased.

As the constituents of liquid fuel are the same as those of coal, the same formula may be used to calculate the heat values, or calorific values, of the two kinds of fuel; that is,

$$Q = 14{,}600\,C + 62{,}000\left(H - \frac{O}{8}\right) + 4{,}000\,S$$

in which Q = calorific value, in heat-units per pound;
C = percentage of carbon, expressed decimally;
H = percentage of hydrogen, expressed decimally;
O = percentage of oxygen, expressed decimally;
S = percentage of sulphur, expressed decimally.

Thus, if a fuel oil has 83.3 per cent. of carbon, 12.5 per cent. of hydrogen, 0.5 per cent. of sulphur and 3.7 per cent. of oxygen its theoretical calorific value is

$$Q = 14{,}600 \times 0.833 + 62{,}000\left(0.125 - \frac{0.037}{8}\right) + 4{,}000 \times 0.005 = 19{,}645 \text{ heat units.}$$

This, it must be remembered, is but the approximate heat value, based on the chemical composition of the oil. A more reliable estimate of the heat value may be obtained by making a calorimetric test of a sample of the fuel oil.

The calorific values of oils vary according to the localities from which they are derived and range from about 17,000 to 21,000 heat units per pound. The Texas and California crude oils used in power-plant work seem to have a calorific value averaging about 18,600 heat units per pound.

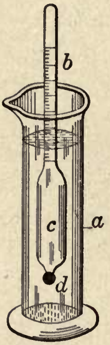


FIG. 1.—Hydrometer for determining density of oil.

Fuel oil and crude oil are usually not quite so heavy as water, bulk for bulk; that is, the specific gravity of oil is ordinarily less than that of water. As a general rule, however, in the purchase and sale of oil fuel the specific gravity is not directly mentioned; instead, it is implied by stating the density in degrees Baumé, or the reading of a Baumé hydrometer allowed to float in the oil.

The method of determining the density of an oil by means of the hydrometer is shown in Fig. 1. A sample of the oil is put into the deep glass *a*, and the hydrometer is lowered into the oil, in which it will float and soon come to rest. The hydrometer consists of a glass tube *b*, at the lower end of which are the chamber *c* and the bulb *d*. The large part *c* is filled with air, and the bulb *d* is filled with quicksilver. The former causes the

hydrometer to float, and the latter keeps it in an upright position.

The stem *b* is graduated with a series of divisions, the lowest one being marked 10. When the hydrometer is put in a vessel of pure distilled water, it sinks until the graduation marked 10 is even with the surface of the water. In other words, 10 deg. Baumé, or 10 deg. B., as it is usually abbreviated, corresponds to a specific gravity of 1, or the specific gravity of pure water.

When the hydrometer is put into a vessel containing oil that is lighter than water, it sinks farther than it did in water, and some other graduation greater than 10 comes even with the surface of the oil. The number of this graduation then indicates the density of that particular oil, in degrees Baumé. For example, if the graduation marked 26 came level with the surface of the oil, the density of the oil would be 26 deg. Baumé.

If the density of an oil lighter than water is given in degrees Baumé, the corresponding specific gravity may be found by using the formula

$$G = \frac{140}{130+B}$$

in which G = specific gravity of oil;
B = density, in degrees Baumé.

For instance, if an oil has a density of 20 deg. Baumé its specific gravity is

$$G = \frac{140}{130+20} = 0.933.$$

To enable the specific gravity for any Baumé reading to be found quickly, without any calculations, the curve

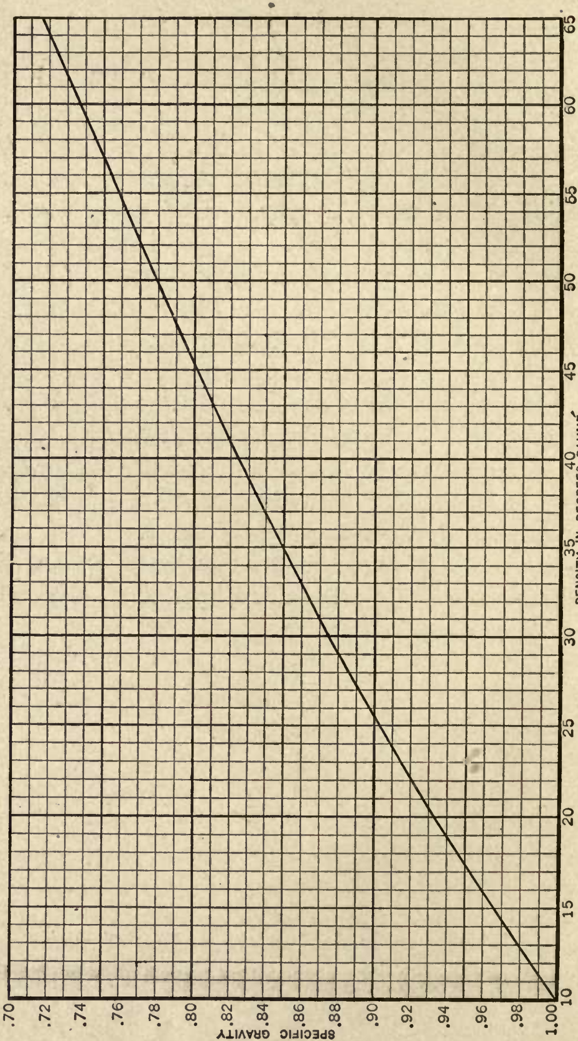


FIG. 2.—Curve showing relation of specific gravity and density.

shown in Fig. 2 is given. For example, suppose that it is desired to find the specific gravity of an oil having a density of 19 deg. Baumé. On the horizontal scale locate the division corresponding to 19, which is the first vertical line to the left of that marked 20. From the point where this vertical line meets the curve follow horizontally to the scale at the left-hand edge of the diagram. It will meet the scale at a point that corresponds to 0.94. This is the desired specific gravity. In other words, a Baumé reading of 19 deg. corresponds to a specific gravity of 0.94.

The same diagram may be used to find a Baumé reading corresponding to a given specific gravity, by reversing the foregoing method. Suppose that it is desired to find the Baumé reading of an oil having a specific gravity of 0.91. Having located the point corresponding to 0.91, midway between 0.90 and 0.92 on the left-hand scale, follow horizontally to the curve and then down to the bottom scale. The point thus reached will be at the first division to the left of 25, corresponding to 24. Hence, a specific gravity of 0.91 corresponds to a Baumé reading of 24 deg.

If possible, the density of oil should be determined at a temperature of 60 deg. Fahr., as the formula and the curve will give the correct equivalent specific gravity only under this condition; however, it may not be convenient to do this in all cases. If the temperature of the oil sample is greater or less than 60 deg. Fahr., it should be noted, so that the specific gravity corresponding to the Baumé reading may be corrected for the difference in temperature.

A higher temperature than the standard, 60 deg.

Fahr., causes the oil to expand, and the specific gravity calculated from the Baumé reading will therefore be too low. A lower temperature than 60 deg. Fahr. will cause the oil to become more dense, so that the specific gravity corresponding to the Baumé reading will be too high.

The correction amounts to 0.0004 for each degree Fahrenheit. That is, if the temperature is less than 60 deg. Fahr., the observed specific gravity must be reduced by an amount equal to 0.0004 times the difference between the observed temperature and 60 deg. Fahr.; and if the temperature is above 60 deg. Fahr., the observed specific gravity must be increased by an amount equal to 0.0004 times the difference between the observed temperature and 60 deg. Fahr.

To illustrate, suppose that a sample of oil is tested at a temperature of 46 deg. Fahr. and found to have a density of 30 deg. Baumé. The specific gravity corresponding to this reading is 0.875 with oil at 60 deg. Fahr. But in this case the oil has a temperature 14 deg. lower than the standard. Hence, the observed specific gravity, 0.875, must be reduced by $0.0004 \times 14 = 0.0056$, and the corrected specific gravity then becomes $0.875 - 0.0056 = 0.8694$, which is the true specific gravity of the oil.

Again, suppose that at a temperature of 80 deg. Fahr. an oil showed a density of 25 deg. Baumé, equivalent to a specific gravity of 0.9032. As the temperature of the sample is 20 deg. in excess of the standard, the observed specific gravity must be increased by $0.0004 \times 20 = 0.0080$, giving a corrected value of $0.9032 + 0.0080 = 0.9112$.

Particulars as to the flash point, firing point, specific gravity, and calorific value of various American oils are given in Table I. These values are taken from a table published in the *Iowa Engineer* of October, 1905, and cover the main oil fields of the United States, with the exception of Ohio. The calorific values were obtained by tests made with a Parr calorimeter. It may be noted that the calorific values of crude oils from any particular district vary but little. The reduced oils, or those from which some of the lighter constituents were removed, gained in specific gravity and did not lose in calorific value; also, the flash point was raised considerably. In a number of cases, double sets of values are given. These are the results of tests on samples obtained from different companies in the same field.

Table II is given because it is a summary of a large number of tests made on the petroleums of the San Joaquin Valley, California, by the Government Bureau of Mines. The detailed report of the tests is contained in Bulletin 19. The composite samples referred to in the table were made up by taking equal weights of all the samples from a given locality and mixing them. For example, the composite sample of Kern River oil was made up of 30 grams from each of the 40 samples previously tested.

TABLE I.—AMERICAN FUEL OILS

Name of oil, or locality	Flash point, deg. Fahr.	Firing point, deg. Fahr.	Specific gravity at 60 deg. Fahr.	B.T.U. per pound
CALIFORNIA				
Giant Oil, Kern county	240	305	0.9669	18,401
Shamrock, Kern county	119	147	0.9349	18,900
Sunset, Kern county	222	296	0.9664	18,732
Whittier, Los Angeles county	148	208	0.9465	17,822
COLORADO				
Florence, Fremont county	164	205	0.8807	18,103
INDIANA				
Whiting, fuel oil	212	318	0.8654	19,400
KANSAS				
Erie, Neosho county	157	208	0.9006	18,714
Altoona, Wilson county	130	181	0.8697	19,210
LOUISIANA				
Jennings, Calcasieu county	194	233	0.9050	20,193
Jennings, Calcasieu county	192	219	0.9063	19,908

TABLE I.—AMERICAN FUEL OILS—*Continued*

Name of oil, or locality	Flash point, deg. Fahr.	Firing point, deg. Fahr.	Specific gravity at 60 deg. Fahr.	B.T.U. per pound
PENNSYLVANIA				
Fuel or gas oil	156	173	0.8370	19,690
Butler county crude	128	180	0.8387	20,560
Distillate, fuel oil	232	280	0.8880	19,700
TEXAS				
Corsicana, Navarro county[1]	196	274	0.9080	19,855
Spindle Top, Jefferson county	165	219	0.9221	19,663
Spindle Top, Jefferson county	163	212	0.9177	19,720
Sour Lake, Jefferson county	108	214	0.9074	18,856
Sour Lake, Jefferson county	136	211	0.9230	18,910
Saratoga, Hardin county	161	226	0.9195	19,263
Saratoga, Hardin county	180	242	0.9305	19,665
Humble, Harris county	166	214	0.9261	19,649
Humble, Harris county	124	228	0.9202	18,040
Reduced crude	326	380	0.9498	19,297
Asphalt oil	376	....	0.9767	20,442
Steamer oil	268	322	0.9265	19,291

[1]A fuel crude oil; contains 10 per cent. of water.

TABLE II.—OILS OF SAN JOAQUIN VALLEY, CALIFORNIA

Oil field	Flash point, deg. Fahr.	Firing point, deg. Fahr.	Degrees Baumé at 60 deg. Fahr.	Water, per cent.	Sulphur, per cent.	B.T.U. per pound
Kern River						
Average of 40 samples...	226	266	15.16	0.5	0.83	18,553
Composite sample.......	216	262	14.78	0.5	0.89	18,562
Coalinga						
Average of 62 samples...	190	230	17.52	0.2	0.59	18,727
Composite sample.......	162	217	17.29	0.4	0.60	18,720
McKittrick						
Average of 26 samples...	189	239	16.37	2.0	0.78	18,508
Composite sample.......	165	228	15.83	1.5	0.74	18,335
Midway						
Average of 29 samples...	172	210	16.34	0.3	0.83	18,613
Composite sample.......	142	189	16.14	0.5	0.82	18,565
Sunset						
Average of 25 samples...	192	235	14.37	1.7	1.02	18,478
Composite sample.......	160	214	14.26	0.4	1.06	18,419

CHAPTER II

REQUIREMENTS FOR EFFICIENT BURNING OF OIL FUEL

The first essential for the successful burning of crude oil or fuel oil is that it must be atomized or broken up into a fine spray or mist; next, it must be thoroughly mixed with a sufficient amount of air to insure its complete combustion; and, finally, the combustion must take place in a furnace of suitable size and shape. These three requirements must be met in every power plant in which liquid fuel is to be used.

When crude oil was first tried as a fuel for steam boilers, attempts were made to burn it by running it into shallow pans and igniting its surface. This was simply following the old methods applied in the case of coal. For, as the coal was spread out in the form of a bed of fairly uniform thickness on the grates, so was the oil spread out in a shallow sheet. This method, however, was wholly unsatisfactory and unsuccessful and was soon abandoned. The reason for its failure was that oil differs so greatly from coal.

With coal the effect of the heat is to drive off the volatile matter in the form of gases, which, mixing with the air passing through the bed of fuel, burn and generate sufficient heat to ignite the solid carbon remaining on the grates. This bed of burning carbon then furnishes the heat required to ignite succeeding charges of fresh fuel.

With oil, there is no incandescent bed of fuel. The oil does not burn in the liquid form. Before it can burn it must be changed to a vapor, or volatilized, and this is done by the action of heat. The action may be illustrated by the burning of a common wax candle, as shown in Fig. 3.

When the wick of a candle is lighted the heat due to the burning melts some of the wax just below the flame, and the melted wax is at once carried up the wick by capillary action. As it comes closer to the flame it grows hotter and hotter, until at length it reaches the boiling point and passes into vapor. This vapor mixes with the air and thus forms a combustible mixture, which burns above the tip of the wick. Part of the heat due to its burning is used to melt and vaporize more of the wax, and the burning is thus rendered a continuous process.

FIG. 3.—Flame of wax candle.

It will be observed that the flame of a candle varies in color. Just around the tip of the wick there is nothing to be seen. This transparent section *a* is the vaporized wax, before it has had a chance to mix with air and burn. Around this is another transparent section *b* that has a bluish tinge. Here the vapor has mixed with some air and is being partly burned. Farther up, there is more opportunity for the mixing of a sufficient quantity of air, and the flame there becomes yellow or yellowish white.

That part of the flame that is tinged with blue indicates

incomplete combustion, because the supply of oxygen in the air that mixes with the vapor is not sufficient to burn the carbon to dioxide. This portion of the flame does not have so high a temperature as the yellowish portion where the combustion is complete.

As a further experiment to show that the crude oil will not burn in the liquid form, a live coal or a blazing stick may be dropped or thrust into a vessel containing the oil. Instead of firing the oil, the live coal will be quenched or the flame of the stick will be extinguished by the oil, for the simple reason that the oil is vaporized so slowly that the inflammable gas produced is not sufficient to support continuous combustion.

The object of atomizing the oil, or dividing it into a fine mist or spray, can now be understood. By separating the body of oil into a great number of fine particles, each particle will have its surface exposed to the heat and will be more readily vaporized than a large bulk of oil. The finer the mist or spray, the more easily will the vaporizing occur. This can be shown by a very simple example. If oil is broken up into a series of drops each 0.1 in. in diameter, the ratio of the surface area to the volume of each drop is sixty to one. But if the drops are 0.01 in. in diameter, the ratio of area to volume is 600 to 1. That is, a drop of oil 0.01 in. in diameter will expose ten times as much surface per unit volume as a drop 0.1 in. in diameter. The finer the particles, therefore, the greater will be the amount of external surface per unit volume exposed to the action of the heat and the more rapidly will the oil turn to vapor.

When the oil has been properly vaporized, it must be

thoroughly mixed with air in the correct proportions to produce complete combustion. This may be done by allowing the air to enter the furnace through openings in the floor or the ashpit, somewhat after the manner in which it is admitted to the furnace of a coal-burning boiler. Again, it may be admitted through the same openings as those through which the burners are introduced, in which case the air sweeps over the burners. But it is more than probable that both methods will be used at one time, so that part of the necessary air will be admitted by each.

The third requirement for the efficient use of oil fuel is a furnace of suitable design and construction in which the combustion may take place. The common furnace used for solid fuel will not ordinarily answer the purpose without alterations.

The coal-burning furnace can be fired intermittently, for there is always a bed of incandescent fuel on the grates so that when the fresh coal is added the incandescent portion will fire the green fuel. But the injection of the liquid fuel is continuous, and the conversion of the freshly admitted oil from the liquid to the gaseous state must be accomplished by a part of the heat of the oil that was burned just before. As there is no fuel bed, the heat must be stored in the lining of the furnace. In other words, the furnace is lined with firebrick, which becomes highly heated and acts as a heat reservoir and equalizer.

The chamber in which the combustion of the liquid fuel takes place should not be bounded by cold metal surfaces. For if the partly burned gases strike such surfaces they will be chilled, combustion will be checked, and there will

be a loss of heat and probably the formation of smoke. By having the combustion occur in a firebrick furnace, however, the chilling is prevented, and when the gases have been burned completely they may be led against the boiler tubes and surfaces without danger of producing smoke.

CHAPTER III

Methods of Spraying Oil Fuel

The atomizing of liquid fuel, or the breaking up of the oil into a spray or mist, so as to enable the air to mix thoroughly with it, may be accomplished in a number of different ways. The most common method is that in which a current of steam or a blast of air is directed into or across the flow of the oil so as to divide it into fine particles. Another way is to subject the oil to a high pressure and then to allow it to escape through small orifices. These orifices are so shaped and placed that the escaping oil is expanded, scattered and properly atomized. A third method involves the use of centrifugal force. A whirling motion is given to the oil, and the centrifugal force set up causes the oil particles to fly off in the form of spray.

The principles involved in all of these methods are used in modern liquid-fuel burners, but centrifugal force alone is not relied upon to produce the desired atomization. In the lengthy and exhaustive tests made by the Bureau of Steam Engineering of the United States Navy several attempts were made to use an atomizer consisting of a steel disk that was rotated at a high speed and over which the oil was allowed to flow. The earlier constructions warped under the effect of the heat or were wrecked by the centrifugal force developed, but by

altering the construction in accordance with the experience gained from these initial experiments a centrifugal apparatus was eventually produced.

It consisted of a circular disk of saw steel riveted to a hollow pivot that was held solidly in vertical bearings. Buckets or vanes were attached in a circle to the under side of the disk, and a jet of steam from a single nozzle was directed on this series of vanes, thus rotating the disk at a high speed. The oil to be sprayed was forced up through the hollow pivot under a small pressure and overflowed on to the disk at the center. Under the action of the centrifugal force set up by the very rapid rotation, it was flung off at the outer edge, and when ignited by a torch it burned in a ring of flame from 4 ft. to 5 ft. in diameter.

In spite of the fact that a mechanical rotary atomizer had thus been developed, this type has not been adopted in commercial installations using oil fuel. The reason is that the spraying force is derived from the jet of steam, and it is simpler to use the steam directly for spraying, without the introduction of the rotating disk. Also, it is probable, from the results of the experiments referred to, that trouble would arise through warping of the disk and wearing of the pivot. It is true that the flow of the oil across the face of the disk has a tendency to cool it somewhat and thus reduce the warping effect, but the fact remains that the purely centrifugal sprayer has not met with favor.

In connection with pressure spraying from an orifice, however, the centrifugal principle has been used successfully. This combination may be illustrated by the simple

sketch shown in Fig. 4. At the end of the pipe *a* that conveys the oil, the oil passage *b* is tapered down to the opening *c* through which the oil is discharged. The series of slanting vanes *d* on the rod *e* deflect the oil and break it up into a number of currents, each of which has a whirling motion as it enters the space *f* around the end *g* of the rod. These separate currents are intermingled in the space *f*, and on emerging from the orifice *c* they spread as shown by the diverging lines. The oil is forced into the pipe *a* under fairly high pressure, and thus the atomizing is due to both the twisting motion given by the vanes and the expansion following the escape at high velocity from the orifice.

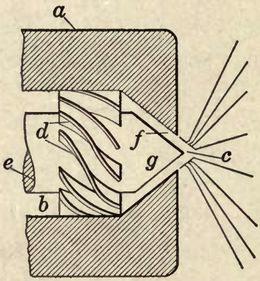


FIG. 4.—Atomizing by pressure and centrifugal force combined.

Though the principle just described could be applied in any installation, it would doubtless be most advantageous in the case of a plant in a district where suitable water is scarce or hard to obtain. For the steam that is used to atomize the oil by direct action goes along with the products of combustion and escapes at the top of the chimney. It is thus lost absolutely, so far as the chances of recovering it are concerned; whereas by using a device similar to that shown in Fig. 4 there is no waste of steam. It is true that steam would be required to run the pressure pumps, but it could afterward be led to some form of condenser and thus recovered for boiler feed-water.

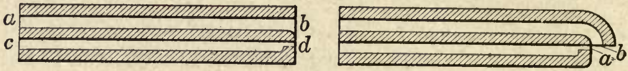
A disadvantage of the system of spraying oil by pressure lies in the fact that the openings through which the oil is forced must not be much greater than 1/16 in. in diameter. An opening of this small size can very easily become clogged by a bit of dirt or a grain of sand; therefore, a strainer should always be inserted in the oil system. The holes in the strainer, of course, must be small enough to catch and retain all dirt of sufficient size to clog the burner. Usually they are made about half the size of the hole or holes through which the oil is sprayed.

By far the greater number of oil-fuel plants use steam or air as the atomizing agent. If steam is used, it is obtained from the boiler being fired or from another boiler in the plant, and if air is used, it is obtained by means of a positive blower or an air compressor. No matter which agent is used, it is led in a sheet or a jet against the oil to be atomized. The mixing of the oil and the steam or the air may take place inside the atomizing device or outside it, but in either case the spraying is due to the expansion that occurs when the steam or air under pressure escapes from the orifice and mingles with the oil.

The device that accomplishes the atomization of the oil is called the burner, though it has nothing to do directly with the combustion. There are two main classes of burners, namely, outside mixers and inside mixers. A common form of outside-mixing burner is shown diagrammatically in Fig. 5. The oil to be atomized is led through the passage *a* and is allowed to flow out and down at the orifice *b*. The steam or air is conducted through the passage *c* and allowed to escape through the narrow orifice *d* just below the oil orifice. The oil that oozes or

drools out is thus caught by the rapidly escaping and expanding steam or air and is thoroughly sprayed. This type is ordinarily termed the drooling burner.

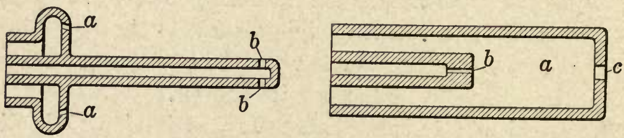
Another form of outside-mixing burner is shown in Fig. 6. It differs from the other only in that the oil passage is turned downward at the outlet end, and the steam or



FIGS. 5 and 6.—Principle of outside-mixing burners.

air issuing from the orifice *a* sweeps directly across the face of the oil orifice *b*. This type is called the atomizer burner.

The type shown in Fig. 7 is called the projector burner and also belongs to the outside-mixing class. In this case, however, the orifices *a* through which the steam or air



FIGS. 7 and 8.—Principle of projector burner and inside-mixing burner.

escapes are at some distance from the oil orifices *b*, so that the steam or air has expanded considerably by the time it meets the oil.

One form of inside-mixing burner is shown in Fig. 8. The oil flows into the chamber *a* surrounding the nozzle *b* through which the steam or air is led, and the latter meets

and mingles with the oil in the chamber, after which both are discharged at *c*. This form of burner is termed a chamber burner.

The diagram in Fig. 9 illustrates the principle of the injector burner. The steam or air flows from the orifice *a* into the passage *b* containing the oil, and the mixture is carried forward with increasing velocity toward the narrowest part *c* of the burner. Beyond this throat the mouth is flared, and the rapid expansion atomizes the oil.

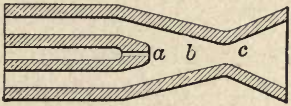


FIG. 9.—Principle of injector burner.

The various types of burners employed in steam plants involve the use of one or more of the foregoing principles. Air is used only in special instances as the atomizing agent, steam being the most common. So far as economy is concerned, there is little to choose between the two, for the reason that the amount of steam required for direct atomizing is about the same as that required to run an air compressor to furnish a sufficient supply of air at the necessary pressure. On the other hand, the addition of a compressor means increased cost for installation over that for a plant using steam directly; also, the amount of piping and apparatus is increased by the use of a compressor, with the natural result that accidents are more likely to happen and so cause partial or complete shut-downs.

The amount of steam used to atomize 1 lb. of oil, whether directly or indirectly, may be taken as about 0.5

lb. for average cases. There are plants in which only about 0.3 lb. of steam per pound of oil is used for atomization, and in the tests made by the Bureau of Steam Engineering some burners used as low as 0.15 lb. of steam per pound of oil. This last was an exceptionally good performance and was unusual. The average plant may consider that its economy is fair if its steam consumption for atomization only amounts to from 0.3 lb. to 0.5 lb. per lb. of oil.

In addition to the steam required for atomizing the oil, there is the steam required for running the pumps by which the oil is supplied under pressure and the steam used in some cases for heating the oil. The amount of steam used for atomization is roughly 2 per cent. of the total amount generated by the boiler; that is, out of every 100 lb. of steam formed, 2 lb. are taken to spray the oil. The oil-pressure pumps and the oil heater require about 2 per cent. more, so that the total steam consumption of the oil system is in the neighborhood of 4 per cent. of the steam generated.

CHAPTER IV

Burners for Oil Fuel

The purpose of the burner is to spray the oil fuel into the furnace; consequently the first requisite of a good burner is that it shall atomize the fuel satisfactorily. As oils are of different densities and viscosities, and as different rates of feed must be used to accommodate the rate of combustion to the load on the boiler, it follows that the burner must be fitted with suitable valves in order that its action may be regulated closely. This regulation applies not only to the oil but to the atomizing medium as well.

A second important feature of a good burner is accessibility for cleaning and repair. It is almost impossible, even after taking the precaution of cleaning and straining, to prevent dirt from being carried along with the oil. As a result, clogging of the oil orifices may occur, and it then becomes necessary to clean the burner. To do this easily and quickly, the burner must be designed so that it may be taken apart readily and without undue labor. In some types of burners the oil and steam currents cause erosion, and in such forms it is necessary to make provision for removing and renewing the worn parts without loss of time.

A form of Gem burner designed particularly for use in small furnaces is shown in Fig. 10. Its body *a* is of cast iron and contains two inlets *b* and *c*, the former for the oil

and the latter for the steam that is used as the spraying agent. The oil flows along the central pipe *d* and escapes at the tip of the burner. The steam passes along the pipe *e* surrounding the oil pipe and is given a whirling motion by the vanes of the whorl *f* near the tip. It then escapes past the conical end of the oil pipe, through an annular opening *g*, sweeping the oil into the furnace.

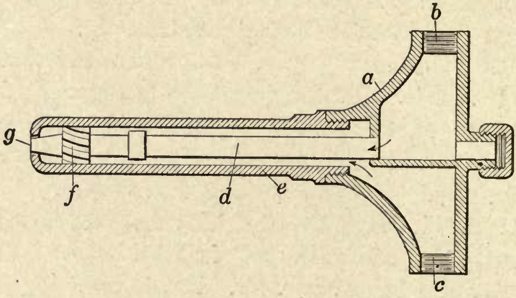


FIG. 10.—Regular Gem oil burner.

As the oil pipe *a* is surrounded by live steam throughout its entire length, the oil becomes well heated in flowing through the burner, and the effect of this heating is to make it more fluid and easy to atomize. The regulation of the flow of oil and steam is accomplished by valves in the pipes attached at *b* and *c* respectively, since there are no moving parts in the burner itself. Should the oil pipe become clogged with dirt, the cap at the back may be unscrewed and a rod may be inserted to remove the obstruction.

An improved form of this burner is shown in Fig. 11. It differs from the form shown in Fig. 10 mainly in that

it has a needle valve included in the burner to enable the oil flow to be regulated more closely. The stem *a*, Fig. 11, of the needle valve is threaded near its inner end and passes through a stuffing-box *b* at its outer end; thus any

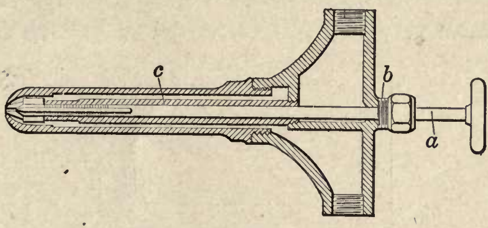


FIG. 11.—Improved Gem oil burner.

expansion of the stem due to increase of temperature does not alter the adjustment of the valve, as it would do if the stem were threaded at the stuffing-box end. The oil surrounds the stem inside the pipe *c* and flows to the nozzle through grooves cut in the side of the stem. The atomi-

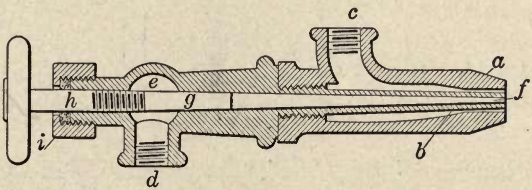


FIG. 12.—Parson oil burner.

zation is effected in the same way as in the simpler type. Each of these burners may easily be unscrewed and taken apart for cleaning.

The Parson burner illustrated in Fig. 12 is similar in

principle to that shown in Fig. 11. The tip *a* of the Parson burner has a passage *b* for the steam, which is admitted through the connection *c*. The oil enters at *d*′ and flows into the chamber *e*, from which it is allowed to pass into the nozzle *f* past the regulating valve *g*. This valve has a very slight taper, and consequently the flow

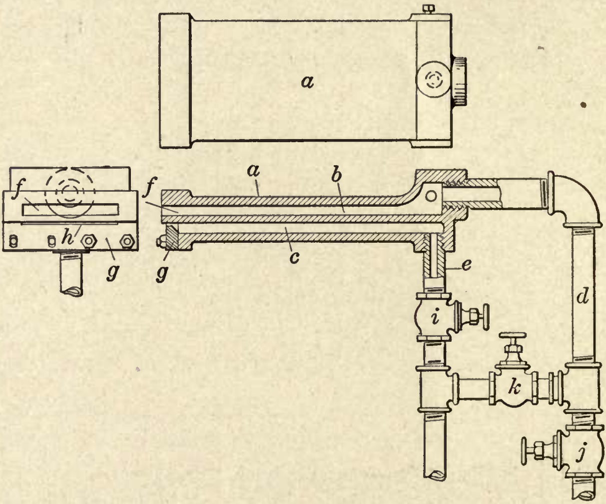


FIG. 13.—Booth oil burner with pipe connections.

of oil can be adjusted with great precision. The nozzle projects through the center of the steam passage in the tip, and the oil is thus heated on its way to the furnace. The valve stem *h* is furnished with a stuffing-box *i* to prevent the leakage of oil.

The Booth burner, shown in Fig. 13, is one that has been used extensively in stationary-boiler practice. The body

of the burner consists of a box-shaped casting *a* that is set horizontally. It contains two passages *b* and *c*, oil being admitted to the former through the pipe *d* and steam to the latter through the pipe *e*. The oil flows outward through the wide, shallow slot *f* at the tip of the burner and drools downward across the end. An adjustable steel plate *g* is bolted across the steam orifice. This plate has a long notch cut in the top edge, forming the outlet *h* for the steam, and on the inside it is beveled or chamfered so as to direct the steam upward toward the orifice. The escaping steam sweeps along the under side of the burner tip and in expanding sprays the oil that runs down from the upper slot. The bolts that hold the plate *g* in place pass through long vertical slots in the plate, and this construction allows the plate to be moved up or down to give the desired depth of slot *h*. This adjustment, of course, is made when the burner is disconnected and not in use.

The arrangement of the piping to the Booth burner is simple. The supply of steam is brought to the burner through the pipe *e*, the flow being regulated by the valve *i*. In the same way a valve *j* in the oil line *d* is used to control the rate of flow of the oil. Between the oil pipe and the steam pipe is inserted a short connection fitted with a valve *k*. This serves as a by-pass to admit steam to the oil passage when it becomes necessary to clean out the passage. The oil valve *j* and the steam valve *i* are first closed and then the by-pass valve *k* is opened. The steam rushes through the oil passage, and its heat and its cutting action together scour the passage clean. The steam passage may be cleaned by removing the plate *g* completely and allowing steam to blow through at full

pressure. The passages in the burner are straight and fairly large, and there is little danger of their becoming clogged frequently.

A form of externally atomizing burner known as the Best burner is shown in Fig. 14. The tip by which the atomizing is accomplished is supported by two pipes *a* and *b* that convey the steam and the oil, and these pipes are made of such length that they will extend through the

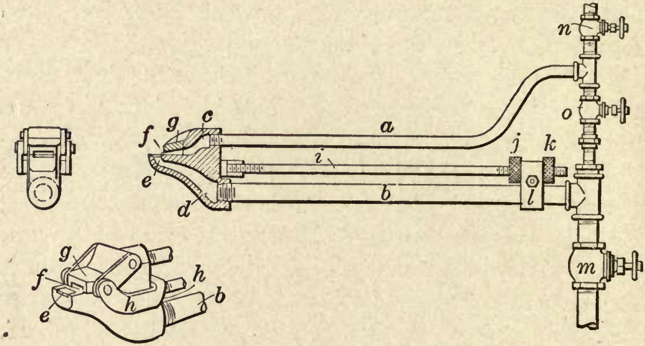


FIG. 14.—Best oil burner.

boiler front and bring the burner just within the front of the furnace. The tip is of cast iron and contains a steam passage *c* and an oil passage *d* connecting with the oil pipe *b*. The oil passage is curved upward, so that the escaping steam sweeps across the face of the orifice *e* at right angles to the direction of flow of the oil, thus insuring excellent atomization. Moreover, it is stated that this arrangement of the two orifices causes the steam to have a sort of ejector action on the oil, with the result that the oil is

drawn toward the orifice *e* and only a low pressure is necessary in the oil system.

The steam orifice *f* is a long, shallow slot in the under face of a hinged lip *g* that during the normal working of the burner is held down firmly against the body of the tip. A fork *h* is pinned to the lip and has fastened to it a rod *i* that is threaded at its outer end and fitted with two adjusting nuts *j* and *k* on opposite sides of the bracket *l*. When the steam passage becomes clogged or choked, these nuts are turned so as to force the rod *i* inward and swing the lip upward. Full steam pressure is then turned on to blow out the obstruction, after which the lip is drawn down on its seat. This may be done from the front of the boiler without disturbing the setting of the burner. The flow of oil is regulated by a cock *m* and the steam supply by a valve *n* in the steam pipe. A by-pass valve *o* is inserted between the steam and oil pipes, to enable the oil side of the burner to be cleaned out readily, as explained before.

The construction of the Best burner is such that there is little or no wear, and the absence of needle adjusting valves and constricted passages reduces the likelihood of clogging. If desired, this burner may be operated with tar as fuel, and it is equally serviceable with heavy oils. The flame produced is fan-shaped and spreads to about the width of the boiler furnace.

The Hammel burner, shown in perspective and in section in Fig. 15, belongs to the inside-mixing type. It consists of three main parts *a*, *b*, and *c*, held together by bolts *d* and *e*. The lower part *a* contains the passage *f* through which steam is admitted to the burner, and the upper

section *b* has the oil connection *g* from which a duct *h* leads downward to a mixing chamber *i* formed by a recess in the under side of the section *c*. The steam flows up from the passage *f* into the chamber *j*, from which three slanting ducts *k*, *l* and *m* lead to the mixing chamber. These ducts are inclined in different directions, and their lower ends are grouped about the end of the oil duct *h* in

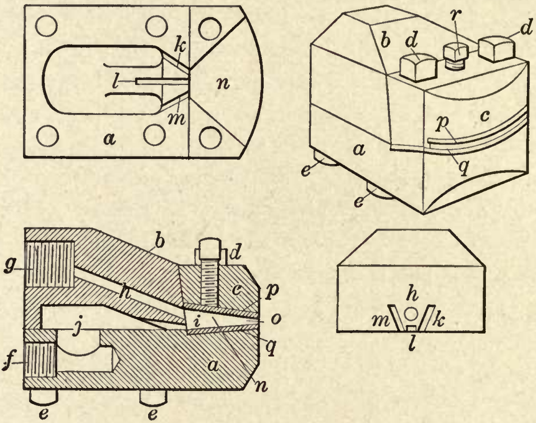


FIG. 15.—Hammel oil burner.

such a way that the escaping steam will mingle thoroughly with the oil in the mixing chamber. From the mixing chamber a flaring opening *n* extends outward to the tip of the burner, and as the steam flows at high velocity and escapes from the wide orifice *o*, it spreads the oil and causes the burner to produce a fan-shaped flame.

Experience with steam turbines has shown that steam traveling at high speed has an erosive effect on pipe

fittings, valves, vanes and other parts that deflect its motion. This cutting action is present likewise in oil burners that use steam as the atomizing agent, and in the Hammel burner the erosion is greatest in the divergent mouth *n*. The wear is due to the cutting action of wet steam and to the presence of particles of dirt and grit in the oil. As a consequence, the upper and lower faces of the opening *n* are lined with steel plates *p* and *q* that take

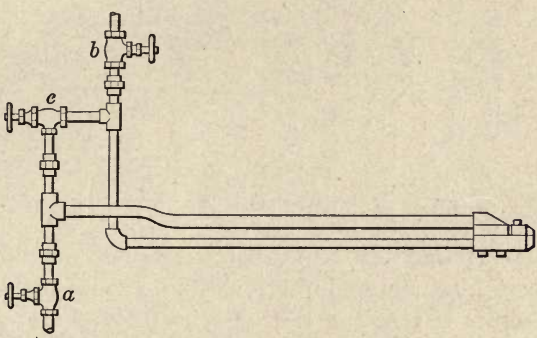


Fig. 16.—Piping for Hammel burner.

all the wear and that may be renewed at small cost when they become greatly eroded. To insert new plates, the bolts *d* are unscrewed and the section *c* is removed, thus uncovering the plates. The set screw *r* serves to hold the upper plate *p* firmly in place when the burner is put together.

The Hammel burner is attached to the ends of the steam and oil pipes, as shown in Fig. 16, and these pipes are made of suitable lengths to allow the burner to project into the furnace through the front of the boiler setting.

The valve *a* regulates the flow of oil and the valve *b* the flow of steam. The valve *c* acts as a by-pass for use in cleaning out the burner in case it becomes choked with grit or carbonized oil.

A perspective view of the Kirkwood burner is given in Fig. 17, and in Fig. 18 is a longitudinal section of the burner, together with the arrangement of the piping.

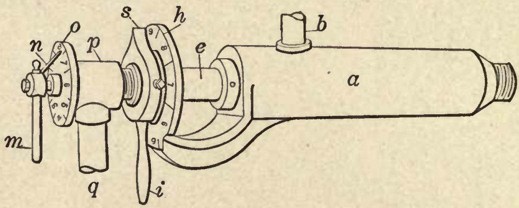


FIG. 17.—Regular Kirkwood oil burner.

The same reference letter is used to designate corresponding parts that appear in both views. The main part of the burner is a hollow casting *a* into which the steam supply pipe *b* is screwed. A plug *c* is inserted at one end and at the other is a stuffing-box *d* through which the pipe *e* extends into the chamber *f*. At its outer end the pipe *e* is threaded and passes through a threaded collar *g* that may be rotated in the bracket *h* by means of the handle *i*. At the inner end the pipe is closed by a plug *j* containing an orifice *k* that may be closed by screwing the long stem *l* inward until it seats against the plug. A handle *m* is fastened to the outer end of the stem and carries a pointer *n* that moves over the dial on the end of the flange *o* on the elbow *p*. The supply of oil is admitted from the pipe *q* through the elbow *p* to the pipe *e*, and it

escapes past the regulating stem *l* through the orifice *k*, where it is picked up by the steam flowing into the chamber *f* and carried through the opening *r* into the furnace.

The handle *i* carries a pointer *s* that moves over a dial on the face of the bracket *h*. Movement of the handle *i*

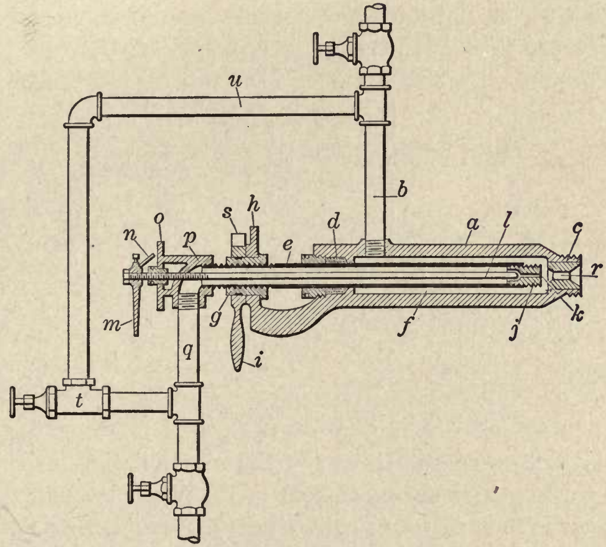


FIG. 18.—Piping for Kirkwood burner.

governs the position of the plug *j* with respect to the plug *c* and so determines the amount of steam used for atomizing the oil. The position of the stem *l* is regulated by the handle *m*, thus governing the rate of flow of oil. The two dials enable the fireman or the boiler attendant to adjust the flow of steam and oil very accurately after he has

once determined the relative proportions that give the best results. By having the regulating valves very close to the point where the steam and oil mingle, as in this burner, the full pressure of each is maintained up to the moment of its escape. The valve *t* is a by-pass valve through which steam may be admitted to the oil pipe to clean it. A slip joint is sometimes inserted in the horizontal section *u* of the by-pass pipe to allow easy sliding when the oil pipe *e* is moved in or out by the handle *i*.

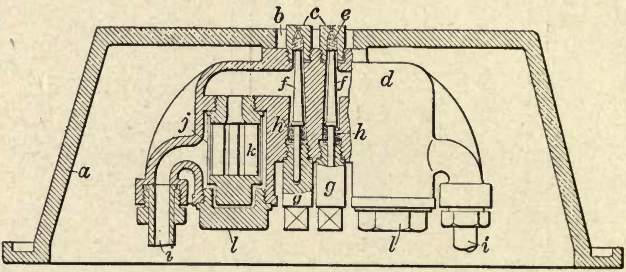


FIG. 19.—Koerting centrifugal spray nozzle.

The setting or adjustment of the oil-regulating stem is not affected by the movement of the pipe *e* because the latter is fixed rigidly to the elbow *p* through which the stem passes, so that any movement of the pipe carries the stem along without changing its distance from the plug *k*.

The construction of the Koerting centrifugal spray nozzle is shown by the section in Fig. 19. The burner consists of a casting *a* that is inserted in a suitable opening in the boiler front and that in turn has an opening *b* through which the tips *c* of the spray nozzles may project. There are two of these nozzles held in the casting *d* that

contains the oil passages and strainers. The tip *c* has at its end a small orifice that is expanded inward to form a chamber to contain the screw *e*, which is carried by a stem *f* that fits in the plug *g*, and is held in position by the pressure of the spring *h*. The oil enters through the pipe *i* and passes through the strainer *j* on its way to the spray nozzle, thus being cleaned. The cage *k* that carries the strainer is screwed into the casting *d* and may be taken out for cleaning by first removing the cap *l*. The oil is sprayed by the whirling set up by the screw in the tip of the nozzle, in combination with the pressure maintained in the oil system. The air required for combustion is admitted through registers around the outside of the casting *a*. The stems *f* are held by springs so that, when heated, they may expand freely. If they were held down by the direct pressure of the plugs *g*, any expansion due to heating would cause them to buckle. The screws *e* may be removed for cleaning by taking out the plugs *g*.

In all of the types of burners heretofore described the relative proportions of the atomizing agent and the oil are under the control of the operator. The Kirkwood burner shown in section in Fig. 20 belongs to that class in which the relative sizes of the openings for oil and steam or air are fixed during the construction or assembling of the burner. The oil and the steam enter through the pipes *a* and *b*, respectively, which are connected to opposite sides of the body casting *c*. The regulation of the flow of oil and steam is accomplished by turning the single handle *d*, which is threaded on the boss *e* and carries the stem *f*. This stem is hollow and is drilled with lateral holes *g* that connect with the oil supply. At its inner end it is tapered

to fit a seat in the plug *h*. A tapered stem *i* is fixed centrally in this plug and projects into the hollow stem *f*. When the handle *d* is turned to the right as far as it will go, the stem *i* closes the duct *j* and at the same time the tapered end of the stem *f* comes against its seat in the plug *h* and shuts off the flow of steam to the tip *k* of the

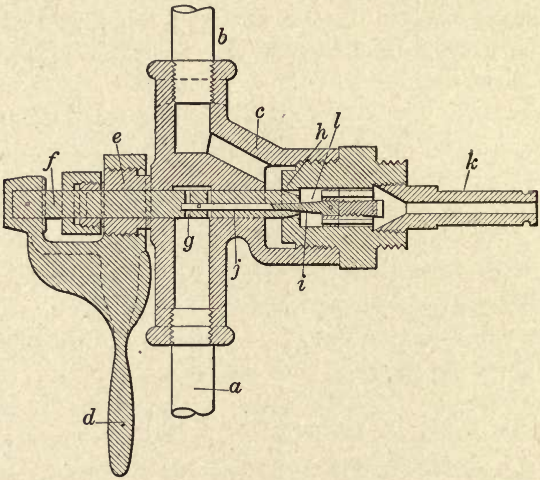


FIG. 20.—Kirkwood burner with fixed steam-to-oil ratio.

burner. In this way the burner is shut down. By turning the handle in the opposite direction, both steam and oil are admitted to the mixing chamber *l*, the relative proportions being governed by the taper of the stems *f* and *i*. The position of the stem is fixed by the manufacturer and cannot easily be changed by the operator. This removes the danger of having an unskilled operator

affect the efficiency of the burner by changing the relative amounts of oil and steam.

The outside-mixing burner in Fig. 21 illustrates a type that is made in a number of forms differing only slightly in detail. The steam pipe *a* and the oil pipe *b* are made

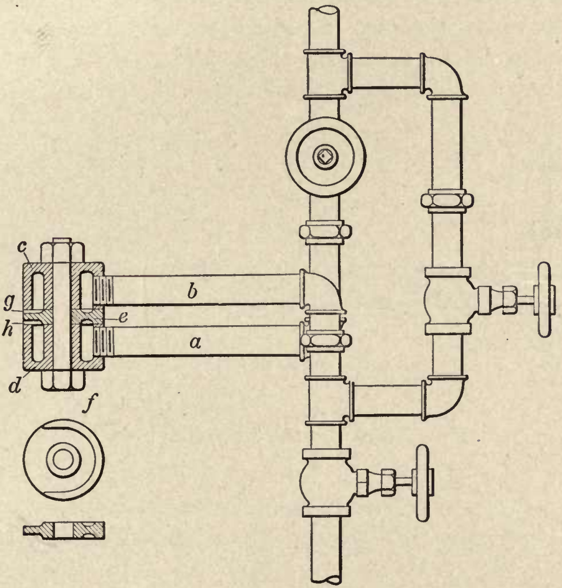


FIG. 21.—Slot oil burner with renewable disk.

of such length as to bring the tip of the burner to the proper point in the furnace. The burner consists of two cup-shaped castings *c* and *d* separated by a narrow disk *e*. The three pieces are of the same diameter and are held together firmly by the central bolt *f*. As shown in the sepa-

rate views, the disk *e* has its rim cut away on both sides for about one-third of its circumference. Thus, when it is bolted between the castings *c* and *d*, two slots *g* and *h* are formed, extending about one-third of the way around the burner. The oil flows through the upper casting *c* and drools over the edge of the disk *e* from the slot *g*. The steam flows through the lower casting *d* and escapes through the slot *h*, meeting the oil and spraying it so as to produce a wide fan-shaped flame. The greater part of

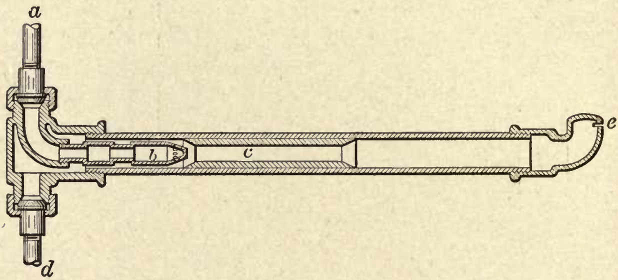


FIG. 22.—Inside-mixing slot oil burner.

the wear due to erosion comes on the disk *e*, which can be renewed when badly worn. The arrangement of the regulating valves for oil and steam and of the by-pass for cleaning is similar to that already described.

Another form of inside-mixing slot burner differing considerably from the Hammel burner is shown in section in Fig. 22. The steam enters at *a* and flows out through the holes in the conical tip of the section *b* into the narrow passage *c*. The oil enters at *d* and flows around the section *b*, being heated in so doing. Under its own pressure,

and aided by the suction produced by the escaping steam, it flows past the conical tip, where it is caught by the steam, broken up, and carried along the pipe *c*. Further mixing of the steam and oil takes place in the chamber and the spray escapes through the slot *e* into the furnace. The spread of the flame may be changed by using slots of different proportions.

CHAPTER V

Cleaning of Oil Fuel

The greater number of burners for oil fuel are constructed with small orifices through which the oil is sprayed. It therefore becomes necessary to take proper precautions to prevent the burners from becoming clogged by particles of sand or other foreign matter. The dirt found in the oil may be in the crude oil as it comes from the well, or it may find its way in during the subsequent transportation and handling of the oil. Oil wells are driven through strata of various earthy materials to pierce the oil-bearing sands, and as a consequence the crude oil issuing from a well contains more or less sand. If the crude oil is used directly as a boiler fuel, it must be strained; otherwise the particles of sand will clog the burners and render them erratic in their operation. The heavier and more viscous the oil, the more easily will it hold and carry with it particles of sand and dirt.

A common method of separating dirt held in suspension in liquids of smaller specific gravity is that of sedimentation or settling. Thus, if oil fuel containing dirt is run into storage reservoirs or settling tanks and there allowed to remain undisturbed for some time, much of the heavier sediment will fall to the bottom by reason of its own greater density. The cleaned oil may then be drawn off at the top. However, this method involves storage of

the oil for a time, with the consequent expense of tanks and pumping machinery; moreover, if the oil is very heavy and viscous, it is by no means certain that the settling method will result in thorough cleaning. It is therefore a wise precaution to use strainers in the piping system that conveys the oil to the burners.

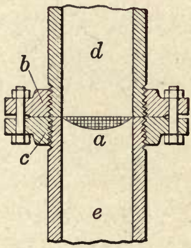
Even the heat treatment or partial distillation that results in the formation of fuel oil cannot be relied on to produce a clean oil; so, where fuel oil is used, strainers should be installed. They not only prevent clogging, but they also lessen the wear on the burner tips due to the erosive effect of grit.

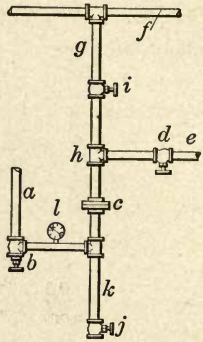
The material of which the strainer is made may be wire netting, gauze or perforated metal. In any case, the meshes or openings should be only about half as wide as the smallest passage or orifice in the burner. Brass wire gauze is the material commonly used, although good strong mosquito netting may be bent into shape to form a strainer. On account of the comparatively large openings in mosquito netting, it should be used only in connection with burners that have no minute orifices, as, for example, the Best burner.

The simplest form of strainer, shown in Fig. 23, consists of a circular piece of wire gauze *a* held between a pair of pipe flanges *b* and *c*; but the simplicity and cheapness of this form are its only commendable features. The oil flowing from the pipe *d* to the pipe *e* on its way to the burners will deposit the sand and dirt on the gauze, and sooner or later the latter will become choked, because it has so small an area. In this condition it will seriously obstruct the flow of oil; therefore, a strainer of this kind

would have to be cleaned frequently. Each cleaning would necessitate opening up the joint at the flanges, so that the gauze could be taken out, and before this could be done it would be necessary to shut off the flow of oil. This type of strainer, therefore, is to be avoided in the simple form shown.

The arrangement of piping shown in Fig. 24 does away with the objectionable feature of breaking the joint to





FIGS. 23 and 24.—Simple oil strainer and piping for strainer.

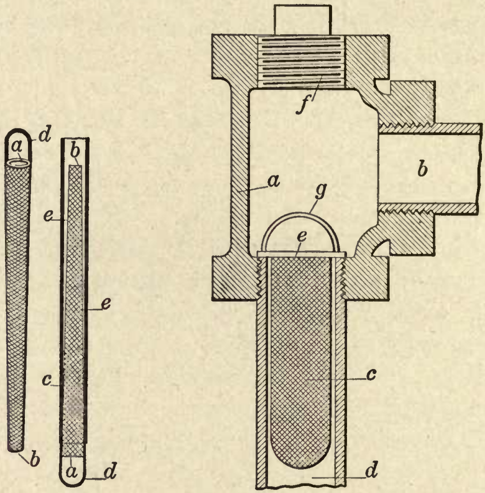
clean the strainer. The oil from the pump flows through the pipe *a* and the valve *b* and passes upward through the wire gauze held between the flanges at *c*, continuing on its way to the burners through the valve *d* and the pipe *e*. The steam line *f* to the burners has a branch *g* that is joined by the T *h* to the oil line and is fitted with a valve *i*. Below the strainer the oil pipe is extended and fitted with a valve *j*. When the burners are working, the valves *i* and *j* are closed and the valves *b* and *d* are open. When

the strainer becomes clogged and requires cleaning, the valves *b* and *d* are closed and a bucket is placed under the valve *j*, which is then opened. Finally, the valve *i* is slowly opened, admitting live steam above the strainer, and this steam, rushing downward through the gauze, will clean it and blow out all the dirt collected beneath it. The valves are then set again for normal working. The valve *i* must be tight or condensed steam will leak into the oil and cause the burners to sputter. The nipple *k* should be fairly long, to form a trap for water and dirt. A pressure gage, shown at *l*, may be attached to the oil pipe on the pump side of the strainer. An abnormal rise of pressure shown on it will indicate that the strainer is clogged and in need of cleaning.

The requirements of a good oil strainer are that it shall stop and hold the solid foreign matter entrained with the oil, that it shall have ample straining surface, so that cleaning may not be required too frequently, and that it shall be constructed and installed so that the cleaning may be quickly and easily done.

The strainer shown in Fig. 25 is made of wire gauze bent into the form of a conical frustum, with the large end *a* open and the small end *b* closed. This form is inserted in the open end of the suction pipe *c* leading to the oil pump and provides a large area through which the oil may pass on its way to the pump. An advantage of having the strainer at this point is that it removes much of the grit that would otherwise cause wear of the pump barrel and plunger. The large end *a* is made slightly larger than the diameter of the suction pipe. The strainer is simply pressed into place in the pipe and is

held there by friction and by the suction effect of the pump. A bail or loop *d* is fastened to the large end so that the strainer may easily be withdrawn when it must be cleaned. The tapering form allows ample space around the strainer, as at *e*, for the oil after it has passed through the gauze.

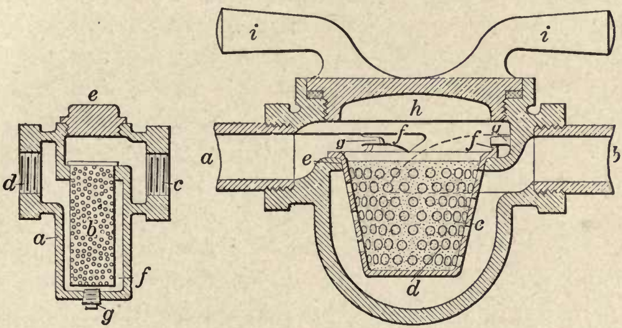


FIGS. 25 and 26.—Suction-pipe strainer and T-fitting used for strainer.

A T-fitting may be used to form a simple and inexpensive strainer, as shown in Fig. 26. The fitting *a* is inserted at a right-angled turn in the oil piping, and the oil, entering through the pipe *b*, passes through the strainer *c* and flows away through the pipe *d*. The strainer is cylindrical in shape and hangs in the pipe *d*, being

supported by a ring *e* that rests on the upper end of the pipe. When the strainer requires cleaning, the plug *f* is removed and the strainer is lifted out by the bail *g*.

The type of strainer shown in Fig. 27 consists of a special casting *a* that is installed in the oil line and that contains the perforated metal cylinder *b* by which the actual straining is done. The oil enters at *c* and flows out at *d*. The cylinder *b* may easily be removed



FIGS. 27 and 28.—Perforated metal strainer and basket strainer for quick cleaning.

after the plug *e* is unscrewed; but, as in the case of the strainers previously shown, the flow of oil must be shut off during the cleaning operation. In order to reduce the period of stoppage to a minimum, it is advisable to have more than one perforated cylinder, so that a clean one can be inserted as soon as the dirty one is removed. Any dirt that passes through the strainer and settles in the bottom of the chamber *f* may be taken out through the hole closed by the plug *g*.

Rapidity in cleaning is the chief feature of the basket strainer shown in Fig. 28. The device is installed in a horizontal section of the oil-pipe line, and the oil flows through from *a* to *b*, being thus forced to pass through the strainer *c*, which consists of a metal basket closed at the bottom, perforated on the sides with large holes, and lined with closely fitting wire gauze *d*. The gauze does the straining and the metal basket simply holds the gauze and prevents it from being torn. If the gauze were not supported and it became clogged, the resistance it would offer to the passage of the oil might cause it to be torn. The basket has a rim that rests on the seat *e* and the inclined ribs *f* on the rim are locked firmly under the lugs *g* by giving the basket a part of a turn. The screw-down cover *h* has a pair of handles *i* by which it may be unscrewed quickly and lifted off, after which the basket is given a twist to unlock it and is then removed. Packing under the flange of the cover prevents leakage of oil.

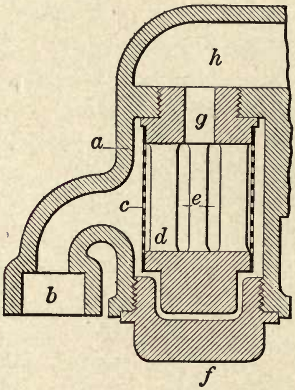


FIG. 29.—Koerting type of oil strainer.

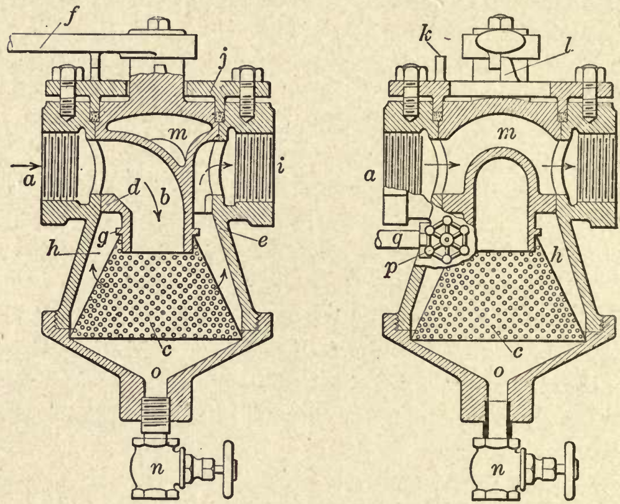
Sometimes the strainer is located in the same casting with the burner, as in the Koerting type, shown in Fig. 29. The casting *a*, of which only a part is shown, contains a pair of burners, each of which is supplied with oil from an

oil inlet *b* through a perforated metal strainer *c*. The strainer is cylindrical and fits snugly over a cylindrical hollow cage *d* that has several long slots *e* in the sides. The cage is screwed into the casting *a*, being inserted through the opening made by removing the plug *f*. The oil from the inlet *b* surrounds the strainer, passes through it and the slots to the interior of the cage, and then flows through the opening *g* to the chamber *h*, which leads to the burner. As each strainer serves its own burner and the two are separate, it is possible to shut down one burner and remove its strainer without affecting the operation of the other burner. On restarting after inserting a clean strainer, the burner that remained working will ignite the fresh spray of fuel from the other burner. This arrangement enables the strainers to be cleaned without completely interrupting the operation of the burners.

Of course, the same object could be accomplished by installing a pair of strainers of any type, with the valves and piping so arranged that while one was out of service for cleaning or repair, the oil could be sent through the other.

A special type of strainer is illustrated in Figs. 30 and 31, which show two different positions of the same device. Corresponding parts in both views are therefore marked with the same reference letters. The important feature of this strainer is that it can be cleaned without taking it apart and without interrupting the flow of oil. Fig. 30 shows a section of the strainer in its normal working position. The oil flows in at *a* and is directed downward by the curved passage *b* into the interior of the conical perforated strainer *c*. The passage *b* is formed in a tapering

plug *d* that fits closely in the body *e* of the device, and this plug may be rotated by means of the handle *f*. The strainer *c* is held down firmly by the collar *g* on the lower end of the plug. The oil, after passing through the cone into the surrounding chamber *h*, flows upward and out at *i*. The plug is held in place by the pressure of the



FIGS. 30 and 31.—Two views of oil strainer arranged for cleaning without removal.

plate *j* bolted to the body *e*, and packing is inserted at the joint to prevent leakage of oil. The handle *f* has on its under side a lug that comes against one or the other of the lugs *k* and *l* set 90 deg. apart on the plate *j*. These limit the rotation of the handle, and consequently of the plug, to a quarter-turn.

When the strainer becomes so dirty as to require cleaning, the handle *f* is given a quarter-turn, which brings the plug into the position shown in Fig. 31. There is a second passage *m* at right angles to the passage *b*, and when the plug is turned the oil flows directly from the inlet to the outlet, without passing through the strainer. Next, the blow-out valve *n* at the bottom of the chamber *o* is opened, after a bucket is set under it. Then the valve *p* is opened, admitting live steam to the chamber *h* from the supply pipe *q*. The steam rushes through the cone in a direction opposite to that in which the oil flows and loosens the dirt, which falls to the bottom of the chamber *o*. It is then blown out through the valve. By the use of this strainer there is no interruption of the oil supply and unstrained oil is sent to the burners only during the brief time required to blow out the dirt. The handle *f* is then swung back to its first position and the strainer resumes its normal working.

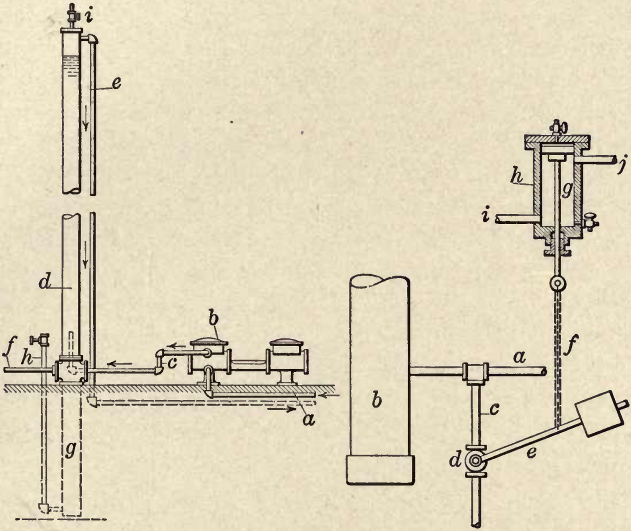
CHAPTER VI

Pumping and Heating of Oil Fuel

In every oil-fuel installation there must be pumps to draw the oil from the storage tanks and deliver it to the burners under pressure. The storage tanks are invariably located underground and therefore at a lower level than the burners. The primary purpose of the pumps, consequently, is to lift the oil from the tanks. The heavy oils employed for fuel are usually too viscous and sluggish to flow freely of their own accord, and so the pumps fulfil the second object of supplying the oil under pressure. In this way the maximum amount of oil supplied may be regulated to suit the demand, regardless of the condition or quality of the oil.

One of the simplest methods of insuring a steady pressure of oil at the burners is to use a standpipe, as shown in Fig. 32. The oil is drawn from the storage tank through the suction pipe *a* by the pump *b* and is discharged through the pipe *c* into the standpipe *d*. This is made of 4-in. pipe and is of sufficient height to give the desired pressure of oil at the burners. An overflow pipe *e* one or two sizes larger than the discharge pipe *c* is connected near the top and is carried back to the storage tank. The speed of the pump is regulated so that the amount of oil delivered is somewhat in excess of that used by the burners. As a result, the standpipe is

constantly kept full to the level of the overflow. The excess of oil simply flows back to the storage tank through the pipe *e*, and as the height of the oil column in the standpipe remains unchanged, the pressure in the oil main *f*, leading to the burners, remains constant. The



FIGS. 32 and 33.—Standpipe used to obtain steady oil pressure and safety device for draining standpipe.

pipe *g* is an extension of the standpipe that serves as a trap for water and sediment contained in the oil. These impurities, being heavier than the oil, fall to the bottom of the pipe *g* and may be blown out at intervals through the pipe *h*. A vent cock *i* is added at the top of the

standpipe to allow the release of gas that enters with the oil and collects above the column.

The object of maintaining a uniform pressure of oil is to insure proper working of the burners and economical combustion. If the pressure were allowed to vary rapidly, the rate of flow of the oil would be changed and the burners would work erratically. Not only that, but the ratio of air to oil would be altered continually and inefficient combustion would result. There seems to be no fixed value for the pressure at which the oil is delivered to the burners. In an extended series of tests made by the Bureau of Steam Engineering of the United States Navy, the pressure varied from 9 lb. to 160 lb. per sq. in., depending on the type of burner, the quality of the oil and the nature of the installation. In the greater number of cases, however, the pressure lies within the limits of 10 lb. and 50 lb. per sq. in.

The required height of the column of oil in the standpipe to produce a desired pressure may easily be calculated, if the specific gravity of the oil is known, by the use of the formula

$$H = 2.304 \frac{P}{G}$$

in which

H = height of oil column, in feet;
P = required oil pressure, in pounds per square inch;
G = specific gravity of oil used.

The height H of the oil column thus found is the vertical distance between the level of the burner orifices and the level of the overflow at the top of the standpipe.

For example, if a pressure of 15 lb. per sq. in. is required and the oil has a specific gravity of 0.96, the height of the oil column must be

$$H = 2.304 \times 15 \div 0.96 = 36 \text{ ft.}$$

With the standpipe arrangement, a considerable quantity is stored at a point above the level of the burner outlets; consequently, if a burner should inadvertently be left open when out of service, the furnace would be flooded with oil. Because of this, some insurance companies refuse to insure plants in which oil is fed by gravity.

The danger of flooding with oil may be overcome by using a safety device, so that when there is no steam pressure for atomizing, the oil in the standpipe will be returned to the storage tank. An arrangement of this kind is shown in Fig. 33. The pipe *a*, leading from the standpipe *b* to the burners, has a branch *c*, in which is fitted a cock *d* that is opened when the weighted lever *e* is allowed to fall. This lever is connected by a chain *f* to the piston rod *g* of a small piston in the cylinder *h*. A steam pipe from the boiler is attached at *i* and a pipe *j* leads to the oil pump, so that the steam supply to the pump must pass through the cylinder *h*. The pressure of the steam forces the piston to the upper end of the cylinder and holds it there, thus keeping the cock *d* closed as long as there is sufficient pressure in the boiler. But when the steam pressure falls below that required to run the pump and atomize the oil, the lever *e* drops and opens the cock *d*, thus allowing all the oil in the standpipe to run back into the storage tank.

Another way of maintaining a uniform pressure of oil is to employ a duplex feed-pump and to put on the discharge pipe a relief valve set to open when the desired pressure is exceeded. A side view of such an apparatus is shown in Fig. 34 in connection with a longitudinal

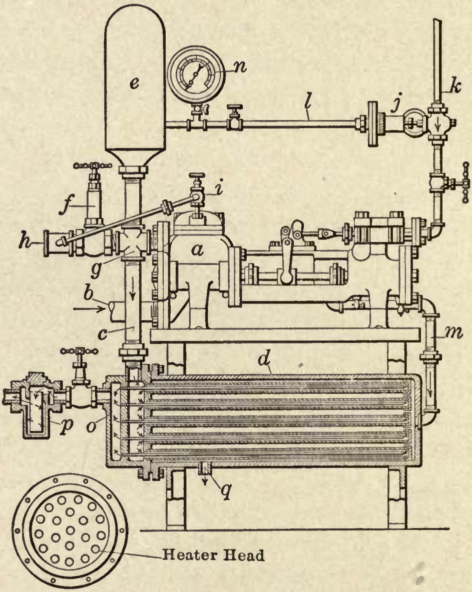


FIG. 34.—Oil-pressure pump with heater.

section of an oil heater. The duplex pump *a* has a suction pipe *b* that leads direct from the storage tank. The discharge from both sides of the pump is led through the pipe *c* to the heater *d*. The air chamber *e* and the relief valve *f* are in communication with the discharge pipe

through the cross *g*. The air chamber cushions the intermittent discharges of oil and prevents shocks. The relief valve, which is merely a spring-loaded valve, is set to the pressure desired at the oil burners. As soon as the pump supplies too much oil, and this pressure is exceeded, the valve rises and the excess of oil is returned to the storage tank by a pipe connected at *h*. Two small pipes lead from the tops of the discharge chambers to the overflow pipe and are fitted with valves *i* to allow any gas collecting in those chambers to be removed.

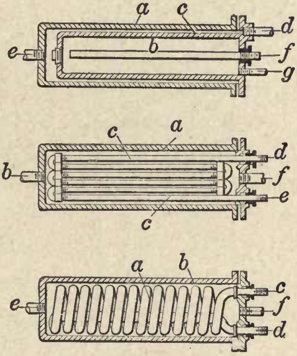
The speed of the pump is regulated automatically by a governor *j* on the steam line *k* to the pump. The governor consists of a flexible diaphragm directly connected to a throttle valve in the steam line. One side of the diaphragm is acted on by the pressure of the oil, which is transmitted through the small pipe *l*, and on the other side by a spring that can be adjusted as desired. When the oil pressure rises too high, the pressure of oil on the diaphragm overcomes the spring pressure and closes the throttle valve somewhat. This reduces the steam supply to the pump and lessens its speed. The oil pressure then decreases and the spring forces the diaphragm back again, opening the valve and admitting more steam. By adjusting the tension of the spring, a very uniform speed of the pump may be obtained. The exhaust from the steam ends of the pump is led through the pipe *m* to the heater, where it is used to heat the oil. A pressure gage is attached at *n* to show the pressure of the oil on the discharge side of the pump.

The object of the heater is to increase the temperature of the oil and thereby decrease its viscosity. The heavy

crude oils are very sluggish, and in this condition they are not easily atomized. If their temperature is low, their rate of flow is still further reduced. Therefore, a heater is inserted in the oil system to render the oil more fluid and easy to break up into a spray. In the illustration the heater is placed between the discharge of the pump and the burners. It consists of a cylindrical outer shell *d* into which the exhaust steam is conducted by the pipe *m*. The head *o* of the heater has two compartments, and into it are screwed two sets of tubes. The larger tubes are closed at one end and fit over the smaller ones, which are open at both ends. The oil from the pump flows into the inner compartment in the head, thence into the larger tubes, around the smaller ones, and finally back through the inside tubes to the outer compartment, from which it passes to the burners through the strainer *p*. The water and uncondensed steam are drawn out of the shell at *q*.

The form of heater shown in Fig. 34 is efficient, because the oil is divided into a number of thin films that pass between the outer and inner tubes while the heat is transmitted through the outer tubes. A much simpler form, and one that is less expensive, is shown in Fig. 35. It consists of two cast-iron cylinders *a* and *b*, one inside the other. The narrow space *c* between the inner and outer shells is filled with the oil to be heated, which flows in at *d* and out at *e*. Steam is led into the inside cylinder through a pipe *f*, and the water and waste steam are removed at *g*. This form is not extremely efficient, because the cast-iron walls are thick and the oil is not divided into very thin sheets.

Another way of arranging the coils in the heater is shown in Fig. 36. The oil flows into the heater shell *a* through the pipe *b* and surrounds the pipe coils *c*, which are made up of straight pipes joined by return bends. Steam is admitted into the top coil through the connection at *d*, and the water is drained out at *e*. The oil flows through the heater from *b* to *f*.



FIGS. 35, 36 and 37.—Forms of oil heaters.

The heater shown in Fig. 36 is more efficient than that in Fig. 35, but the one shown in Fig. 37 gives better heating than either, because the coil *a* that carries the steam has a greater amount of heating surface exposed to the oil. It is made in a continuous coil that fits closely inside the shell *b*. Steam enters at *c* and the condensation escapes at *d*. The oil enters at *e* and is discharged at *f*.

The corrugated film heater shown in Fig. 38 is designed with a view to obtaining a very high efficiency. It consists of two spirally corrugated copper tubes *a* and *b*. These fit very closely, leaving only a thin space between them, and oil is led into this space through the inlet *c*. It flows upward between the two corrugated tubes and passes out at *d*. Steam is admitted through the pipe *e* and flows directly to the interior *f* of the tube *b*. At the same time a branch pipe *g* admits steam to the cham-

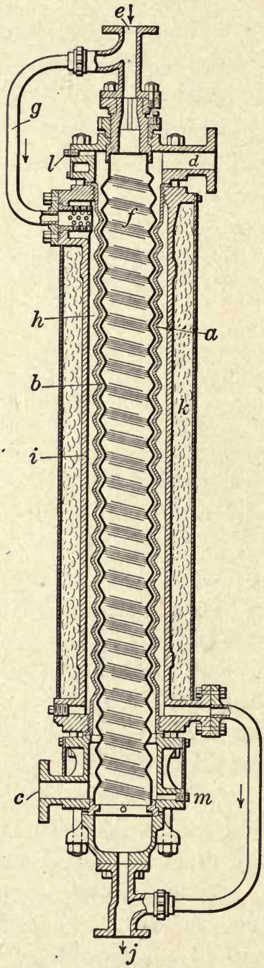


FIG. 38.—Corrugated counterflow oil heater.

ber *h* surrounding the outer tube and formed by the inclosing cylindrical shell *i*. The oil film is thus heated by the transmission of heat inward through the outer tube and outward through the inner tube. The steam and oil flow in opposite directions, so that the warmest oil meets the steam entering the heater. This counter-current adds to the efficiency of operation. The drain pipe *j* serves to remove all condensation from the steam chambers, and the shell is protected by a non-conducting covering *k* that reduces the loss of heat to the surrounding air. The tubes may be removed for cleaning; or the plugs *l* and *m* may be taken out and live steam may be blown through between the tubes. This will quickly and thoroughly clean out all sediment and tarry deposits.

As the heater is placed between the pump and the burners, it is subjected to the full pressure of the oil, and it

should be tested to see that it is capable of withstanding the maximum pressure that may be put upon it. Some makers guarantee their heaters for a pressure of 200 lb. per sq. in., which is well above the point that will be reached in ordinary work. The joints of the steam coils or of the tubes fitted in the head of the heater should be absolutely tight, so that no water can leak into the oil supply. Also, the pipes and tubes should be arranged so that they can expand and contract freely, without springing joints open and causing leaks.

Heating of the oil between the pump and the burners is done to make atomization easier. In some cases, however, it is necessary to heat the oil in the storage tank so that it will flow readily to the pump. This is particularly true of installations in cold climates. There are crude oils that at temperatures of from 30 to 40 deg. Fahr. become so sluggish that they cannot be drawn to the pump, and they must be heated sufficiently to cause them to flow. It is neither necessary nor advisable to heat the entire bulk of oil in the storage tank. A steam coil can be located around the lower end of the suction pipe. This will heat the oil in the immediate neighborhood of the entrance to the pipe and enable it to be drawn up. In any case, the heating must not be carried to a point at which the oil will begin to decompose, that is, break up into its constituent hydrocarbons. The temperature at which decomposition occurs varies for oils of different qualities and from different localities, but usually it does not exceed 180 deg. Fahr.

The temperature of the oil may be observed by a thermometer placed in a mercury cup in the oil line

leading to the burners, as shown in Fig. 39. The pipe *a* conveys the oil to the burners, and into it is screwed a fitting *b* that carries the thermometer tube *c* and the scale *d*. At the bottom is a long cup *e* filled with mercury, in which the lower end of the tube *c* rests. The heat of the oil flowing through the pipe is thus transmitted to the tube and the temperature is registered on the scale.

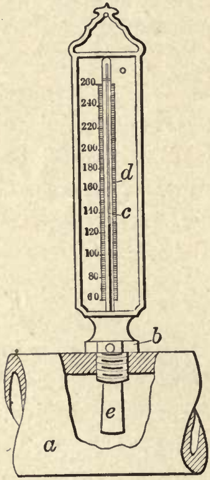


FIG. 39.—Thermometer for finding temperature of oil in pipe.

If the plant is of such character that even a brief shutdown would entail great loss or inconvenience, the oil pump should be duplicated, so that one set of pumps will be in reserve in case the other set fails. This can be arranged by using a system of cross-overs in the piping. Also, it is an excellent plan to have the entire system of oil pipes connected so that live steam may be blown through it to clean it of dirt and tarry matter adhering to it.

CHAPTER VII

OIL-BURNING FURNACES

The arrangement of the furnace of a boiler that is to be fired with oil fuel varies according to the type of boiler and the location of the burner; also, it makes considerable difference whether the boiler setting is originally planned for the use of oil fuel or whether it is altered from the coal-burning type. Details of the arrangements will differ because of the manner in which the air supply is allowed to enter. In view of these facts, it would manifestly be impossible to illustrate all of the many styles of furnaces, but several of them will be given to show their distinctive features.

A form of oil-burning furnace for a return-tubular boiler is shown in section and in plan in Fig. 40. There is a single fan-tailed burner *a* installed in the center of the fire-door. It projects well through the front wall and is surrounded by a short firebrick sleeve or arch *b*. The grates *c* are retained, and on them is laid a closely fitted layer *d* of firebrick that prevents air from rising through the grates except at the extreme rear end. On this layer of brick are placed a number of blocks that support another layer *e*, and this top layer forms a continuous floor from the arch *b* to the top of the bridge wall *f*. The air supply is admitted through the door *g* to the space beneath the grates, whence it flows to the

rear, up through the grates, forward between the fire-brick layers *d* and *e*, and then past the burner into the

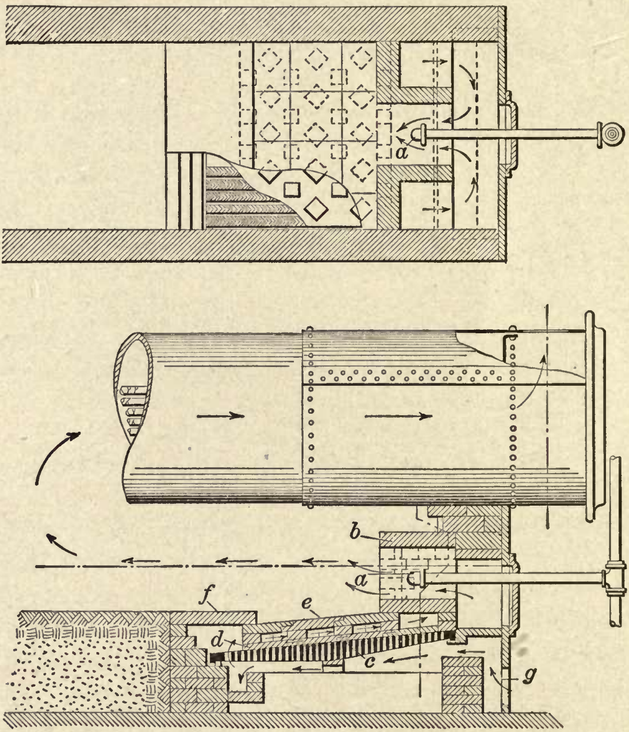


FIG. 40.—Return-tubular boiler with slot oil burner.

combustion chamber, as indicated by the small arrows. The arch *b* and the layer *e* of firebrick are kept at the point of incandescence by the flame from the burner,

and the air in flowing along in contact with the hot brickwork becomes heated to a high temperature before it reaches the tip of the burner. This preheating of the air supply adds to the efficiency of the combustion. All joints or openings around the burner are carefully closed, so that no cold air can leak into the furnace. The entire air supply must therefore pass under the heated slabs *e*.

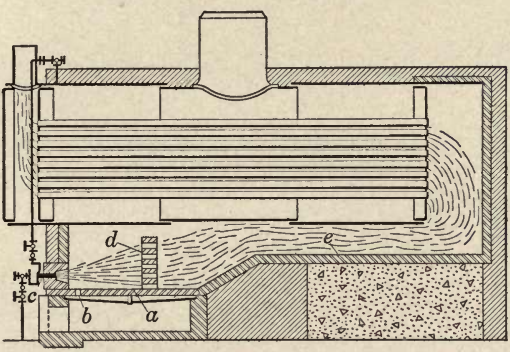


FIG. 41.—Return-tubular boiler with Kirkwood oil burner.

A return-tubular boiler arranged to use a Kirkwood burner is shown in section in Fig. 41. In this case the grate bars are retained but are covered with a closely laid floor *a* of firebrick that has a single slot *b* for the admission of air to the furnace from the ashpit. The burner *c* is set in firebrick in the fire-door opening and the slot *b* is just in front of it. The air on meeting the oil spray unites with it and the flames are thrown toward the rear, where they strike the firebrick pier *d* built on the grates.

This pier is not solid, but forms a sort of checkerwork by which the burning gases are thoroughly diffused and mixed so as to prevent the possibility of incomplete combustion. Beyond the bridge wall the floor *e* is brought level with the top of the bridge wall, so that the hot products of combustion are kept in close contact with the boiler shell. With this arrangement the

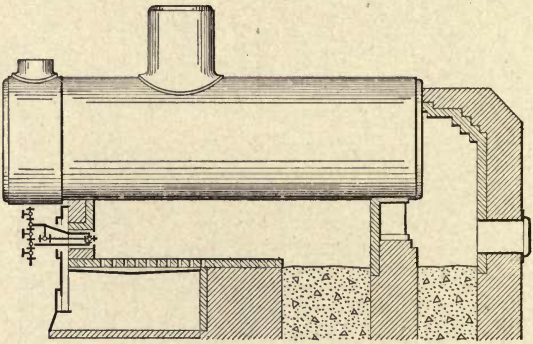


FIG. 42.—Return-tubular boiler with Best oil burner.

flames are directed against the firebrick on the grates and that forming the pier, but not against the boiler shell.

The arrangement suggested for a return-tubular boiler fitted with a Best burner is shown in Fig. 42. The bridge wall is torn down until its top is level with the surface of the grates. On this surface firebrick is laid flat, with air spaces about 1/2 in. wide in the part on the grates. The burner is inserted in an opening in the front wall of the setting, on the center line of the furnace. Its tip is

about 8 in. above the firebrick on the grates and about 2 in. inside the front wall. The flame is thrown out parallel to the grate surface and to the full width of the furnace. The air supply passes up through the openings in the brickwork covering the grates and mixes with the vaporized oil at all parts of the furnace.

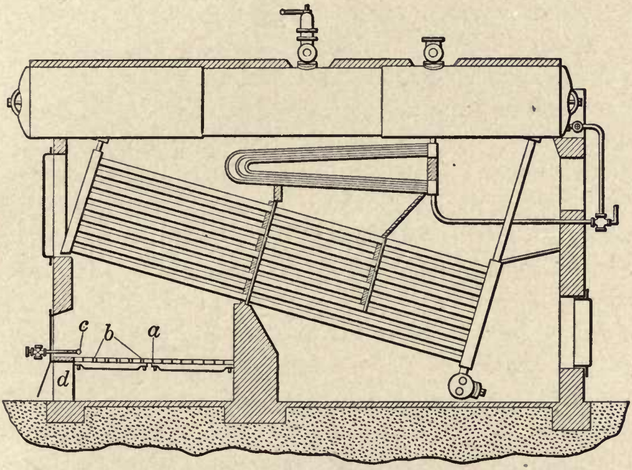


FIG. 43.—Babcock & Wilcox boiler with burner at front.

The furnace arrangement shown in Fig. 43 is for a Babcock & Wilcox water-tube boiler. The grates are covered with a single layer of firebrick *a* laid close together except at the front, where a series of openings *b* are left. The burner *c*, which throws a fan-shaped flame, projects through the fire-door and its tip is just inside the front wall. Thus the flame from the burner is directly

above the openings *b* in the brickwork. The air supply in this case is not preheated to any great extent, because it flows into the ashpit through the door *d* and passes immediately to the combustion chamber through the openings in the grates. The slot in the end of the burner is horizontal, and the sheet of flame thus produced is practically parallel to the surface of the grates.

The arrangement shown in Fig. 44 is also for a Babcock & Wilcox boiler. It differs markedly from that previously illustrated in that the burners are located at the back of the furnace, against the bridge wall, instead of at the front. The grates are removed completely and a firebrick floor *a* is built to cover the entire area from the front wall to the bridge wall. As may be seen in the plan view, this floor is carried by the side walls of the furnace and by the three sets of bearing bars *b* that rest on the side walls and on two longitudinal piers. The burners *c* are set in recesses in the front face of the bridge wall, just above the level of the floor, and are of the Hammel type. They direct fan-shaped flames forward over the flat floor *a*. The three passages formed beneath the bearing bars contain the oil and steam pipes leading to the burners and also serve as air ducts by which the air supply is led to the burners. Inasmuch as the floor *a* is kept incandescent, the air flowing along beneath it is heated highly before being allowed to flow upward past the burner into the furnace.

The three transverse rows of firebrick just in front of the burners are not laid end to end, but small spaces are left, in order that some of the air may rise directly through these openings and mingle with the oil vapor

above the floor. This is done to prevent carbon from being deposited on the brickwork just below the tips of the burners. To the remainder of the floor *a* a coating of

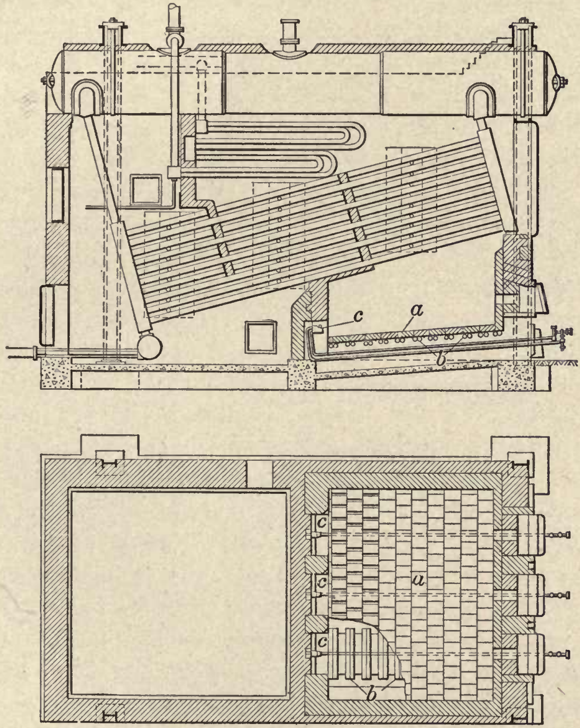


FIG. 44.—Babcock & Wilcox boiler with burner at bridge wall.

fireclay wash is given to fill up all joints and prevent air from flowing up through except as provided by the slots. The passage for each burner is separate from the others,

and the air supply to each burner can therefore be regulated by the ashpit door, independently of the others.

The object to be gained by placing the burners at the bridge wall and directing the flames forward is a better utilization of the combustion space. When the air and the gasified fuel unite and burn, the heat generated causes the temperature of the gases to rise, and they expand in volume as a consequence. By having them projected toward the front of the furnace, where the area of vertical cross-section is greater because of the upward slant of the tubes, the increased volume of the gases is accommodated by the increased space and the rate of flow of the products of combustion is thus rendered more nearly uniform. It will be observed that the front wall of the furnace is protected from the heat of the flames by a firebrick lining.

A form of furnace construction used in connection with a Heine water-tube boiler is shown in Fig. 45. The bridge wall is torn out completely and the whole floor is brought to the level of the bottom of the ashpit. On this surface two layers of firebrick are placed, as at *a* and *b*, separated by bricks *c* laid on edge and so supported as to leave an air passage *d* underneath the lower layer. The air supply enters through the ashpit doors, flows to the back end of the boiler through the passage *d*, then forward between the layers *a* and *b*, and escapes, highly heated, into the furnace just beneath the burner *e*. The burner is of the slot type and throws a fan-shaped flame that spreads to the sides of the furnace. The inclination of the burner is such that the flame is about parallel to the rows of tubes.

The Stirling water-tube boiler arranged for burning oil with a Best burner is shown in section in Fig. 46. The grates are removed and the sloping floor of the furnace is covered with firebrick laid flat in rows 9 in. from center to center. On top of this firebricks are laid on edge and 9 in. from center to center. The top layer of firebrick is laid flat, with 1/4-in. air spaces; thus the air supply is ad-

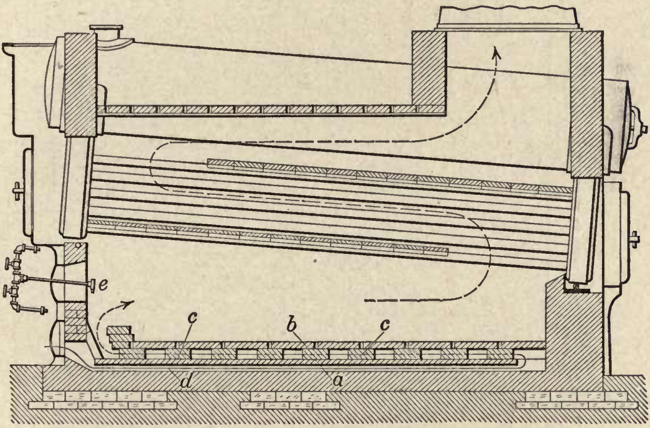


FIG. 45.—Heine boiler with preheating of air supply.

mitted over the whole bottom of the furnace after being heated by contact with the brickwork. The burner *a* is inserted through the front wall about 8 in. above the grate and parallel thereto, the tip extending into the furnace about 2 in. Over the tip is constructed a firebrick arch *b* forming an igniting chamber. The arch is brought to incandescence by the heat of the flame, and in case the action of the burner is momentarily interrupted, as by a slug

of water carried over with the oil, the spray will be reignited by the hot brickwork when the burner continues its operation. The bridge wall is constructed with a fire-brick facing and a flared top, so that the flames striking

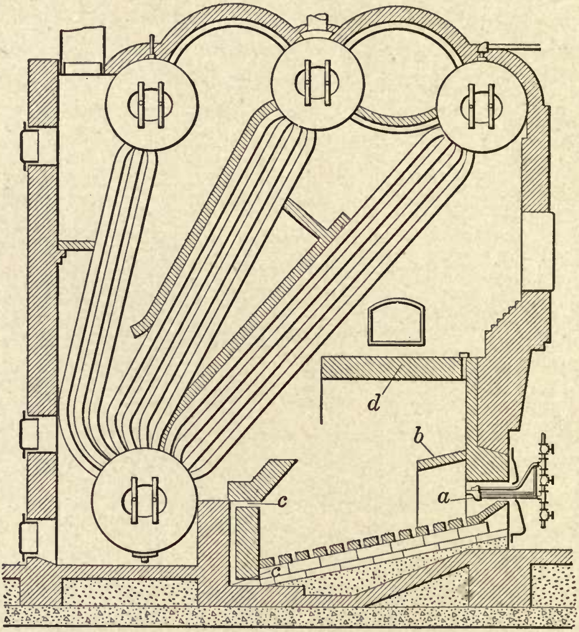


FIG. 46.—Stirling boiler with auxiliary air duct.

into the pocket thus formed are turned back on themselves. This is done to prevent the flames from striking directly against the tubes. An auxiliary air duct *c* is formed in the bridge wall. It connects with the passages

beneath the furnace floor and admits air to the upper part of the flame when the fires are being forced. At such a time there is a tendency to form carbon monoxide at the top of the flame, and the air admitted through the duct *c* supplies the oxygen required to convert this to dioxide. The arch *d* is retained and serves to deflect the gases toward the front bank of tubes.

If desired, the burner can be put at the rear end of the furnace, as in Fig. 47. The arrangement in this case is

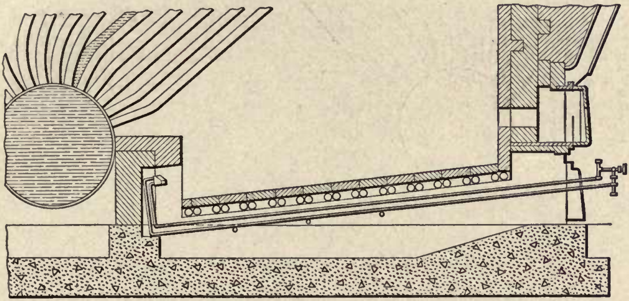


FIG. 47.—Stirling boiler with burner at back of furnace.

like that for the Babcock & Wilcox boiler fired from the rear. The air ducts are formed beneath the floor, there being one for each burner, and the burners are protected somewhat by being set in recesses in the bridge wall. The arch over the furnace is omitted, and the front wall is heavily protected with firebrick.

One way of altering the usual furnace construction of the Stirling boiler so as to adapt it to the use of oil fuel is shown in Fig. 48. The rear half of the grate is removed and a brick pier *a* is substituted. A firebrick floor *b* is

built over the top of the pier and the remainder of the grate surface, and air spaces from 1/4 in. to 1/2 in. wide are left between the bricks on the grates. The arch usually found inside the furnace, above the fire-door, is removed entirely, because the burner *c* is installed at about the height of the top of this arch. The burner is of the slot type and is inclined so as to project the flames downward into the angle or pocket formed by the firebrick floor *b*

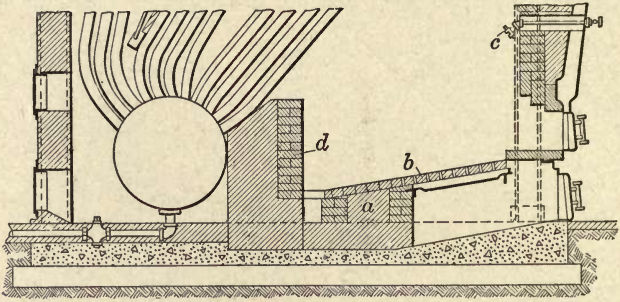


FIG. 48.—Stirling boiler with burner set high at front.

and the bridge wall *d*. The flames thus are given a rebound before they enter the first pass among the tubes. The air enters through the space below the grates and flows up through the space in the brickwork into the furnace.

From an examination of the settings that have thus far been described the following conclusions may be drawn: The furnace of an oil-fired boiler, particularly in those parts against which the flames strike, must be lined with a good quality of firebrick so as to protect the outer walls and the boiler and to resist the high temperatures pro-

duced. There should be a combustion chamber of ample size, in which the gases and the air may meet and commingle thoroughly, so that combustion may be complete before the resulting products of combustion are brought against the comparatively cool boiler surfaces. If combustion is not completed before the gases strike the metal parts of the boiler, the consequent chilling will prevent further combustion and cause smoke to be formed. If it seems likely that the flames will strike the boiler, baffles or arches should be set up to prevent direct contact. This is particularly necessary in the case of the blow-off pipe of a return-tubular boiler, when the blow-off is carried straight down through the gas passage at the rear end of the boiler. It is advisable to preheat the air supply before admitting it to the furnace.

Oil fuel is used as an auxiliary to coal in some cases. In one electric power station oil burners are installed with the idea of helping out on peak loads and for the purpose of banking the boilers. The arrangement of the furnace of one of the boilers is shown in Fig. 49. At the front there are the usual grates *a* on which coal fires are carried for the normal operation of the boilers. Behind the bridge wall *b* the burners are installed, as shown at *c*. The combustion chamber for the oil is formed by the baffle *d*, the floor *e*, the wall *f*, and the side walls of the setting. After combustion, the hot gases from the oil burner pass forward over the bridge wall and travel along with the gases rising from the grates. The air supply to each burner is admitted through the passage *g* that contains the steam and oil pipes.

By this arrangement it is possible to fire the boiler at both ends, using coal and oil at the same time. The result is the same as would be obtained by increasing the rate of combustion with coal alone; that is, the steaming

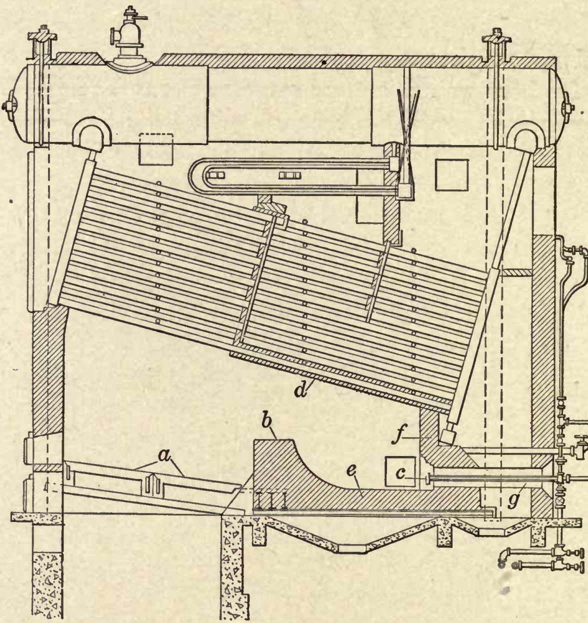


FIG. 49.—Coal-burning boiler with oil used for banking and peak loads.

capacity of the boiler is greatly increased. Of course, the oil burners are used to supply the additional steam demanded by a peak load. Under normal load the coal fires only are used; but as soon as a sudden increase of

load comes on, the oil burners are put in action, and in a very short time the capacity is equal to the increased demand. This rapidity of response to sudden changes of load forms one of the strongest advantages of oil fuel. By adopting the scheme here outlined the boiler horse-power may be increased two-thirds, without increasing the number of boilers.

During periods when the load is light oil is used to bank the boilers. There are four burners to each boiler, and one of these is connected so that it can be operated independently of the others when the boilers are to be banked. At this particular plant the oil costs more per heat unit than the coal; yet it is found more economical to use oil for banking, because the combustion is more efficient with the oil than with the slow coal fire.

CHAPTER VIII

Installation of Oil Burners

When installing oil burners the piping should be provided with unions near the burners, to facilitate the work of taking them down when they must be repaired. This point is very clearly illustrated in Fig. 50, which shows the piping for a Gem burner *a*. The oil flows to the burner through the valve *b* and the connecting pipes,

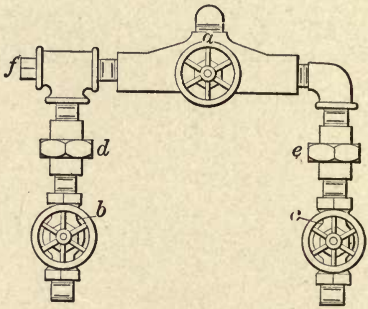


Fig. 50.—Piping for Gem oil burner.

and the steam for atomizing is admitted through the valve *c* and the branch to which it is fitted. The unions *d* and *e* enable the burner to be detached from the system very easily and quickly. The plug *f*, when removed, allows the connection to be cleaned out. The valve *b* is closed, and a cap is placed over the end of the burner

so that the steam will back up in the burner and blow back through the oil connection, cleaning it.

The pipe connections for a Best burner are shown in Fig. 51 in a diagrammatic way. The burner is located at *a* and the oil and steam lines are attached on opposite sides. There are unions *b* and *c* to facilitate the removal of the burner and stop valves *d* and *e* for oil and steam respectively. In addition, there is an oil-regulating cock *f* between the stop valve *d* and the burner, to enable the flow of oil to be regulated with great precision.

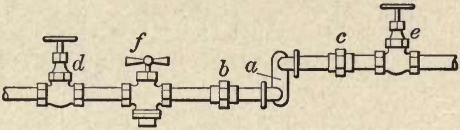


FIG. 51.—Piping and oil-regulating cock for Best burner.

An end view and a vertical section of the regulating cock are shown in Fig. 52. It consists of a conical plug *a* that fits a conical seat in the body *b* of the cock and that is held snugly in place by the upward pressure of the spring *c*. The spring is kept in position by the extension *d* on the bottom of the plug and by the cap *e*. The latter can be unscrewed so as to allow the plug and the spring to be removed from the body of the cock. The oil flows through a triangular opening *f* in the plug. The opening is made triangular in form so as to insure close regulation of the oil. The opening *g* in the body of the cock on the outlet side of the plug is rectangular in shape and the outline of this opening is dotted around the opening in the plug. By turning the plug slowly,

the amount by which the triangular opening overlaps the edge of the rectangular outlet can be varied very gradually, thus giving close adjustment of the oil supply to the burner. The packing *h* around the stem of the plug is compressed under the screw cap *i* and prevents leakage of oil around the stem.

The cock is opened fully or closed completely by giving the handle *j* a quarter-turn. There is a lug *k* on the handle, and it comes against a stop *l* cast on the body of

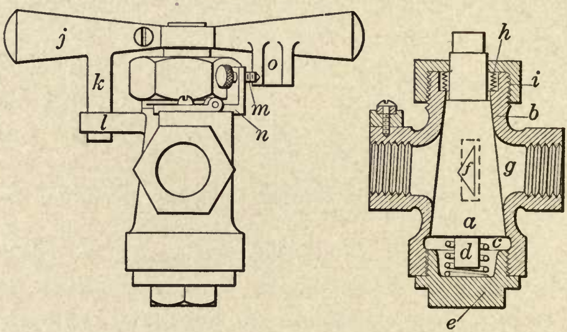


FIG. 52.—Oil-regulating cock.

the cock when the plug is turned to the closed position. Also, there is a knurled screw *m* in a bracket *n* fastened to the body of the cock. When the plug is turned to open the cock, the lug *o* comes against the point of the screw and the handle can be turned no farther. The screw can be adjusted to give any desired amount of opening of the cock, and the cock can be opened and set instantly to this position. The bracket *n* is hinged, and if the cock is to be opened to its full extent, the bracket is

simply swung upward and backward, taking the stop screw *m* out of the way of the lug *o*.

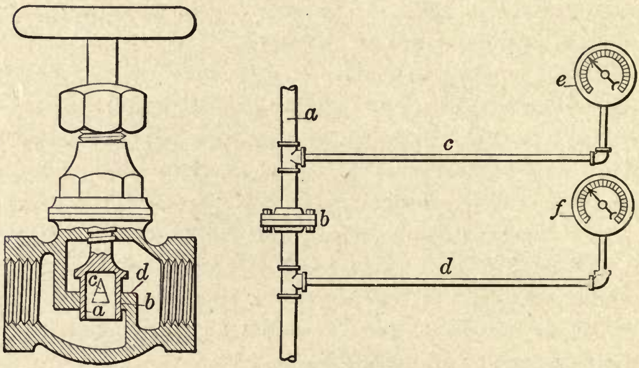
A form of valve for regulating the flow of oil with extreme nicety is shown partly in section in Fig. 53. The inner end of the valve stem carries a hollow cylinder *a* that fits snugly in a circular hole in the seat *b*. In the side of the cylinder is cut a triangular opening *c*, so that, when the stem is screwed out, the point of the triangular opening rises above the face *d* of the seat and allows the oil to pass through. The higher the stem is drawn, the greater is the amount of opening.

Owing to the penetrative nature of oil fuel, the piping should be carefully put together and all joints should be tight. In making up the connections the pipe threads should be perfect and should be cut in oil, so as to be smooth and free from cracks. If the threaded end is made too long the pipe will screw into the fitting too easily and leakage may result. It is better to cut the threads so that it will require a considerable force on the pipe wrench to put the pipes together, as this will be more apt to give tight joints.

The pipes leading to and from the storage tank are usually permanent and are not likely to be taken apart, so the joints may be made up with a cement of litharge and glycerine to insure tightness. If it is possible to do so, elbows should be avoided in installing the oil piping, as the foreign matter in the oil will collect at these fittings and eventually clog the pipes. It is preferable to employ bends of long radius instead of elbows. It will be found advisable to arrange the piping in such a way that the oil can be turned off and live steam sent through the

oil lines to loosen the deposits of asphalt or tarry matter and blow them out of the pipes.

The proportions of the furnace and the style of oil burner to be used will govern the number of burners that must be supplied in a given installation. To illustrate, if a furnace is long and narrow, a single burner giving a long, conical flame will be sufficient; but if the furnace is short and narrow, a single fan-tailed burner will give



FIGS. 53 and 54.—Oil-regulating valve and arrangement for finding amount of steam used by burners.

the desired results. In case the furnace is wide, two or more burners may have to be installed. Some makes of burners are so constructed that they can be made to throw a long, narrow flame or a short, wide one. It may be said that, as a rule, one burner for each 6 ft. or 7 ft. of width of furnace will be required. The capacity of the burner must also be taken into account. One

manufacturer guarantees a capacity of from 5 to 350 boiler-hp. with a single size and type of burner. Another rates his burners at from 75 to 100 boiler-hp. each. Still others manufacture different sizes of burners of the same type, each size corresponding to a certain capacity.

The location of the burner is a matter that cannot well be considered apart from the furnace arrangement. In the case of the return-tubular boiler, it is common to find a burner in the center of each fire-door; but if sufficient capacity can be obtained by the use of a single burner it may be inserted through an opening between the fire-doors, cut through the boiler front and the front wall of the furnace. Whatever the location of the burner or burners, the furnace space should be utilized as far as possible. This is one reason why it is found advisable in some instances to locate the burners at the rear end of the furnace in inclined-tube water-tube boilers.

The importance of supplying dry steam for atomizing cannot be overestimated. A steady white flame is produced if the steam is dry; but if water is carried along with the steam the burner sputters and combustion is retarded. The presence of water in the steam may be due to priming of the boiler or to condensation in the pipe line leading to the burner. One way of avoiding such moisture is to superheat the steam, which can be done very easily by running the steam pipe from the boiler to the burner through the furnace or the boiler breeching. Such an arrangement, however, is not always convenient. It is advisable, then, to put a steam separator on the steam line near the burner, in which the steam will be freed of its moisture. This is accomplished by an

abrupt change in the direction of flow of the steam, by centrifugal force set up during a whirling motion caused by spiral guides or vanes, or by the separating action of baffle plates. The moisture collecting in the bottom of the separator may be removed through a drip or by an automatic trap.

The economy of a burner is measured by the amount of steam it uses to atomize a pound of oil. There are several ways of determining this, but the simplest way is to condense the steam that issues from the burner in a given time, weigh it, and compare it with the amount of oil used in an equal period. A tank of cold water is set on scales and weighed accurately. Then the burner, with the same piping and connections as are used in ordinary operation, is submerged in the tank. The steam valve is then opened to the same extent as during the normal working of the burner and is left open for a definite time, say, a quarter of an hour.

The steam escaping from the burner will condense in the water in the tank, increasing the amount of water and the temperature. At the end of the given time the burner is removed and the tank and its contents are weighed again. The increase of weight represents the amount of steam used in the observed time. The accuracy of the test may be checked by taking the initial and final temperatures of the water in the tank and calculating how much steam at the usual working pressure would be required to produce the observed rise of temperature in the known weight of water. This result should agree fairly well with the increase of weight of the water in the tank. The amount of oil used in the same length of time can be calculated from

the readings of the telltale on the tank, or from the readings of the meter on the oil line, if there is one installed.

This method is very simple and the apparatus is commonly available; but there is the disadvantage that during the test the burner does not operate under the same conditions as in service. When the burner is atomizing oil the issuing steam meets the resistance of the viscous oil in the mixing chamber or at the orifice, whereas in the testing tank the resistance is due to the water. These resistances differ more or less, and the greater the difference the greater the error in basing the economy of the burner on the results of the test. It is probable that the water will offer less resistance than the oil, so that the test will show the burner less economical in steam than it really is.

A more nearly accurate test may be made by using the apparatus shown in Fig. 54. The vertical pipe *a* leads to the burners and conveys the steam for atomizing. Between the two flanges *b* on this pipe is a thin plate in the center of which a hole 3/8 in. in diameter is drilled. The steam flows through this orifice in the plate on its way to the burners. On opposite sides of the flanges the pipes *c* and *d* are connected, leading to the steam-pressure gages *e* and *f*. The gages register the steam pressures on opposite sides of the orifice in the plate, and these pressures vary according to the amount of opening of the steam valve, and hence according to the rate of flow of steam. A series of tests are made with different openings of the steam-regulating valve, observing the pressures on the gages and catching and condensing the steam in a weighing tank filled with cold water. In this way a

table is made up showing the amount of steam flowing through the plate in a given time for each different combination of pressures. After such a table is once compiled the steam consumption of the burners at any time may be found quickly by observing the pressures registered by the gages and then noting the corresponding steam rate in the table.

CHAPTER IX

Storage of Oil Fuel

The method of storing the supply of oil for an oil-burning boiler plant is a matter to which careful consideration should be given. The objects that should be kept in mind while planning the storage system are safety and capacity.

For the average boiler plant of small or medium size the oil supply is usually stored in cylindrical steel tanks like that shown in Fig. 55. The tank is built up of steel plates, has dished ends and is usually buried in the ground at such a level that its top is below the level of the tips of the burners. The object of this arrangement is to prevent flooding of the furnaces or of the boiler room with oil in case a burner valve is accidentally left open; for with the tanks below the level of the burners the oil will flow back by gravity if a valve is left open at the burners. As the tank is usually covered with earth, it should have a good coat of tar or some protective paint to enable it to resist the effects of dampness.

The common sizes of oil tanks for boiler installations are 8 ft. in diameter by 28 ft. long and 9 ft. in diameter by 33 ft. long. The former has a capacity of about 10,500 U. S. gallons and the latter a capacity of approximately 15,700 U. S. gallons. In either case, a good

quality of steel plate 5/16 in. thick should be used, and the heads should be made of 3/8-in. plate.

There should be no openings in the bottom, sides or ends of the storage tank. Such openings as are required should be at the top. The largest opening required is that for the manhole, as at *a*, Fig. 55, and this should be fitted with a screw-down cover. There must be a flange *b* for connecting the suction pipe *c* that leads to the pump, and another *d* for the overflow pipe *e*, leading back from the standpipe or from the pressure pumps.

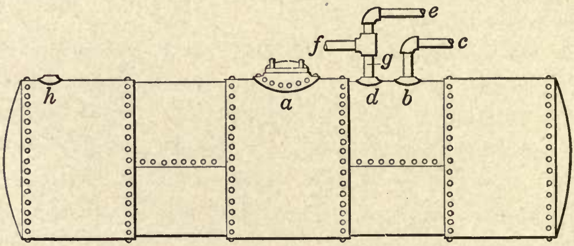


FIG. 55.—Oil-storage tank with connections.

The filling pipe *f*, by which the oil is run into the tank from the tank car, may be attached by a T to the overflow pipe and both connected with the tank through the nipple *g* and the flange *d*. Again, there must be a flange *h* to which a ventilating pipe can be connected. If the oil around the end of the suction pipe must be heated, so that it will flow readily to the pumps, then it will be necessary to add two more flanges for the pipes that convey the live steam and carry off the condensation.

The work of designing and constructing the tank

should be put in the hands of a manufacturer familiar with the requirements of steam-boiler construction, because the tank must be absolutely oil-tight. All petroleum oils are very penetrative in their character, and if there is any suspicion of looseness at the seams or around the rivets, the oil will find its way through. For this reason the rivet holes should be drilled, or else punched and reamed, and the seams should be thoroughly calked.

The capacity of the tank or tanks installed depends on the size of the plant and the frequency with which shipments of fuel may be delivered. If the plant lies fairly close to the oil fields, so that there is little delay in obtaining fresh shipments, it is unnecessary to carry a large supply in storage, and the tank or tanks may be made of such size as to hold oil enough to run the plant for a week. A tank 9 ft. in diameter and 33 ft. in length will contain one week's supply of oil for a plant of 500 boiler-hp. operating ten hours a day at an average efficiency of 75 per cent.

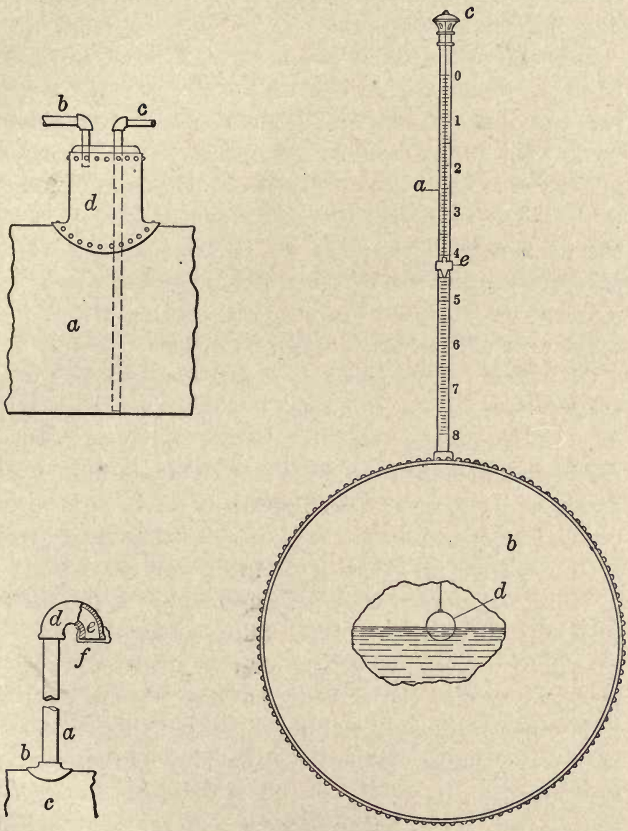
If the plant is so located that shipments of oil may be delayed and cannot be relied on to arrive with regularity, it may be necessary to provide storage capacity for a month or more of continuous working, so as to make reasonable provision against the possibility of a complete shut-down.

The location of the storage tanks must be carefully considered, in order to conform to the requirements of the underwriters. For example, if the tank is placed above the ground level, it must be situated at least 200 ft. from inflammable property, so as to minimize the danger to that property in case the oil should catch fire.

In the case of a plant located in a town or a city, this requirement would be hard to meet, owing either to the difficulty of finding available storage space or to the high cost of such space. On this account, storage tanks are usually placed underground. The requirements for an underground tank are that it must be at least 30 ft. from the nearest building and that it must be at least 2 ft. below the surface of the ground. In either form of installation the top of the tank must be below the level of the lowest pipe in the oil system, so that the plant cannot be flooded with oil.

For ease in filling, the storage tank should be near the railway siding on which the tank cars are run, and at a lower level, so that the oil may be run from the tank cars into the storage tank by gravity. This is the least expensive method of making the transfer. If the tank is not at a low enough level to allow this method of filling to be used, the oil may be pumped out of the tank car into the tank, the suction pipe extending into the tank car and the discharge pipe being connected to the filling pipe of the storage tank.

Air pressure has been used as a substitute for pumping in some instances. The method by which it is employed is shown in Fig. 56, in which *a* represents the central part of the tank car. Two pipes *b* and *c* are connected to the dome *d*. The former is short and extends only a little distance into the dome. The other is long enough to reach to the bottom of the tank car and is connected to the filling pipe of the storage tank. All cther outlets from the tank car are kept closed, and compressed air is admitted through the pipe *b*. The pressure of the air



FIGS. 56, 57, and 58.—Arrangement for emptying tank car; simple form of vent pipe; vent pipe and telltale.

on the surface of the oil forces the oil up the pipe *c* and over into the storage tank.

It is stated that tank cars are tested under a pressure of 40 lb. per sq. in., but it is wise to use a compressed-air pressure of not more than 10 lb. per sq. in. A pressure of 10 lb. per sq. in. will balance an oil column approximately 24 ft. high, and it is doubtful whether the storage tank will ever exceed this height above the bottom of the tank car. The use of air pressure in this way is strongly condemned by some of the tank-car lines, and placards are attached to their cars warning users not to employ this method of emptying the cars.

Of course, compressed air is not available in a great many plants, as most of them use steam to atomize the oil. Steam pressure would force the oil out of the tank car just as well as air pressure, but the steam would condense, and the water would settle to the bottom of the car and be forced out with the oil into the storage tank. As a result, steam is not used in this way.

While the storage tank is being filled with oil, the air originally contained in it is being displaced and driven out. To afford a means of escape for this air, a vent pipe is attached to one of the flanges at the top of the tank. This pipe serves another purpose, also, in that it allows the escape of gases rising from the oil. At the ordinary temperatures at which the oil is kept in the storage tanks, there is a certain amount of evaporation, the lighter and more volatile constituents changing to the gaseous form. The vent pipe, open to the outer air, affords easy escape for these gases and prevents the rise of pressure that would result if there were no outlet.

One of the simplest forms of vent pipe is shown in Fig. 57. It consists of a straight piece of pipe *a* about 3 ft. long, screwed into the flange *b* on top of the tank *c*. On its upper end a return bend *d* is screwed, and over the opening *e*, which faces downward, a piece of wire gauze *f* is firmly bound. The downward curve of the return bend prevents any sparks from dropping into the vent pipe and igniting the gases arising from the oil, and the gauze prevents the flame from traveling back into the tank even if the gases are ignited at the opening *e*, outside the gauze.

Another form of vent pipe is shown in Fig. 58. It is a straight pipe *a*, somewhat longer than the diameter of the storage tank *b*, and is screwed into a flange at the top of the tank. At the top of the pipe is a cap *c* that has a number of openings in its under side. These openings allow the escape of air or gases from the tank and are covered with wire gauze to prevent a flare-back.

This particular form of vent pipe serves also as a telltale, that is, as an indicator to show the amount of oil in the tank at any specified time. Inside the cap *c* is a small pulley over which a wire passes. To one end of the wire is attached a float *d*, which falls or rises as the level of the oil in the tank changes. To the other end of the wire is attached a pointer *e*, and as the float falls or rises the pointer rises or falls an equal distance. On the vent pipe, just behind the pointer, a scale is marked, divided into feet and inches, the total length of the scale being equal to the inside diameter of the tank. The position of the pointer then indicates the depth of oil in the tank, in feet and inches. A table may easily be compiled show-

ing the amount of oil in the tank at each inch of depth. Then, when the depth of oil is noted on the telltale, the amount of oil corresponding to that depth can quickly be found.

If compressed air is used as the atomizing agent in the plant, or is otherwise available, the form of indicator illustrated in Fig. 59 may be used. A glass tube *a* of

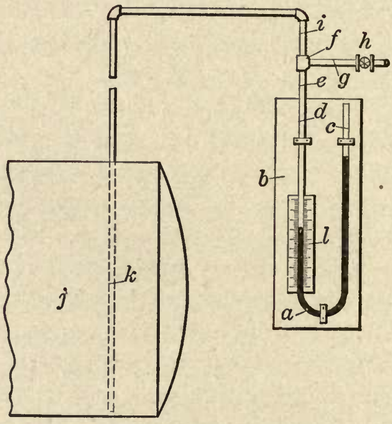


FIG. 59.—Indicator for oil-storage tank.

U-shape is fastened to a board *b* that in turn is fastened to the wall or to some other convenient support. The tube is partly filled with mercury and the leg *c* is left open to the air. The other leg *d* is connected by a rubber tube to a pipe *e* that is screwed into the T-fitting *f*. Two other pipes are connected to the T. That at *g* leads to the compressed-air system and is fitted with a valve *h*. The other pipe *i* leads to the bottom of the oil-

storage tank *j*. All of this piping may be of 1/8-in. wrought-iron pipe.

The action of the indicator is simple. The valve *h* is opened very slightly, so that air leaks past it into the leg *d* of the U-tube and into the pipe *i*. As the air continues to flow into the pipe *i*, the pressure therein grows greater, and this pressure acts on the mercury and on the oil with equal intensity. The result is that the oil in the pipe *k* is forced down until finally it is all driven out at the lower end, and air escapes into the tank. At the same time the increasing pressure of the air forces the mercury down in the leg *d* of the tube and up in the leg *c*. Behind the leg *d* is a graduated scale *l*, and the position of the top of the mercury column in the leg *d* is read on the scale.

The deeper the oil in the storage tank, the greater is the pressure required to force the oil down out of the pipe *k*, and consequently the lower will the mercury be forced in the leg *d*. Every reading of the mercury level on the scale *l* therefore corresponds to a certain depth of oil in the storage tank, and hence to a certain definite quantity of oil. A table is compiled showing the amount of oil in the tank corresponding to each division on the scale. By comparing the reading at any time with the table the corresponding quantity of oil can be found. The accuracy of this device is based on the assumption that practically the same grade of oil is used continuously. If the oil varies in specific gravity from time to time, the scale will not correctly indicate the amount of oil in the tank.

With proper care there is little danger that the oil in the storage tank will catch fire; however, in some installa-

tions a steam pipe is connected to the top of the storage tank, so that live steam may be run direct from the boiler into the tank to smother any fire that may start.

Reference has been made to tables from which the quantity of oil on hand can be determined when the depth of oil in the tank is known. Two such tables are given herewith. Table III shows the amount of oil at each inch of depth in a cylindrical tank 8 ft. in diameter and 28 ft. long, lying in a horizontal position. Table IV shows the amount of oil at each inch of depth in a similar tank 9 ft. in diameter and 33 ft. long, placed in the same position. The values representing the amounts of oil are given in United States gallons and are only approximate, being calculated to the nearest 5 gal.; however, the device used to indicate the depth of oil is likely to introduce slight errors, so that these values are sufficiently accurate for all practical purposes.

The method of using the tables is easy to understand. In the first column are given the depths of oil in inches, or fractions of a foot, and at the heads of the remaining columns are placed the depths in feet, ranging from zero to a value that is 1 ft. less than the full diameter of the tank. To find the amount of oil corresponding to a given depth of oil in the tank, the column headed by the number of feet of depth is first located. Then, in the first column, the number denoting the depth in inches is located. The number that lies on the same horizontal line with this depth in inches, and in the column headed by the depth in feet, is the quantity of oil in gallons.

Suppose that it is desired to find the amount of oil

in a tank 8 ft. in diameter and 28 ft. long when the indicator shows a depth of 3 ft. 8 in. In Table III the column headed 3 is located, and in this column, on the same line with 8 in the first column, is the value 4,705; therefore, the amount of oil at this depth is 4,705 gal.

Again, suppose that the depth of oil in the same tank is exactly 6 ft., that is, 6 ft. 0 in., and the quantity of oil is to be found. There is no zero in the first column to represent 0 in.; but 6 ft. is the same as 5 ft. 12 in. Then, the quantity of oil at a depth of 5 ft. 12 in., or 6 ft., is found in the column headed 5, on the same line with 12, and is 8,470 gal. In the same way, the amount of oil at a depth of 4 ft., or 3 ft. 12 in., is 5,265 gal., and at a depth of 8 ft., or 7 ft. 12 in., the tank is full and contains 10,530 gal.

If the depth of oil is not more than 1 ft., or 12 in., the quantity is found in the second column, headed 0. For instance, if the depth of oil is 9 in., which is 0 ft. 9 in., the amount is 500 gal., because 500 is in the column headed 0 and on the same line as 9 in the first column. The values for the larger size of tank are found from Table IV by the same methods as those described in connection with Table III.

TABLE III.—CAPACITY OF TANK 8 FT. IN DIAMETER AND 28 FT. LONG

Depth in inches	Depth of oil in ft.							
	0	1	2	3	4	5	6	7
	Quantity of oil in United States gallons							
1	20	855	2,180	3,740	5,405	7,055	8,590	9,860
2	55	950	2,305	3,880	5,545	7,190	8,710	9,950
3	100	1,050	2,430	4,015	5,685	7,325	8,825	10,030
4	150	1,115	2,555	4,150	5,825	7,460	8,940	10,110
5	210	1,260	2,680	4,290	5,965	7,590	9,055	10,185
6	275	1,365	2,810	4,430	6,100	7,720	9,165	10,255
7	345	1,475	2,940	4,565	6,240	7,850	9,270	10,320
8	420	1,590	3,070	4,705	6,380	7,975	9,375	10,380
9	500	1,705	3,205	4,845	6,515	8,100	9,480	10,430
10	580	1,820	3,340	4,985	6,650	8,225	9,580	10,475
11	670	1,940	3,475	5,125	6,790	8,350	9,675	10,510
12	760	2,060	3,605	5,265	6,925	8,470	9,770	10,530

TABLE IV.—CAPACITY OF TANK 9 FT. IN DIAMETER AND 33 FT. LONG

Depth in inches	Depth of oil in ft.								
	0	1	2	3	4	5	6	7	8
	Quantity of oil in United States gallons								
1	25	1,075	2,755	4,760	6,930	9,145	11,295	13,260	14,865
2	65	1,195	2,910	4,935	7,115	9,330	11,470	13,410	14,975
3	120	1,320	3,070	5,115	7,295	9,510	11,640	13,555	15,080
4	190	1,450	3,230	5,290	7,480	9,695	11,810	13,700	15,180
5	265	1,585	3,395	5,470	7,665	9,875	11,980	13,845	15,275
6	345	1,720	3,560	5,650	7,850	10,055	12,145	13,985	15,360
7	430	1,860	3,725	5,830	8,040	10,235	12,310	14,120	15,440
8	525	2,005	3,895	6,010	8,225	10,415	12,475	14,255	15,515
9	625	2,150	4,065	6,195	8,410	10,590	12,635	14,385	15,585
10	730	2,295	4,235	6,375	8,590	10,770	12,790	14,510	15,640
11	840	2,445	4,410	6,560	8,775	10,945	12,950	14,630	15,680
12	955	2,600	4,585	6,745	8,960	11,120	13,105	14,750	15,705

CHAPTER X

Combustion of Oil Fuel

The efficiency of combustion of oil fuel is dependent on the furnace in which the burning takes place. The burner should give a finely atomized spray of oil, but the furnace must be of such size and shape as to enable the oil to be vaporized, mixed with the required quantity of air and burned to carbon dioxide before the resulting products of combustion are allowed to come in contact with the boiler surfaces.

The effect of too small a furnace is to cause incomplete combustion. The oil is sprayed into the furnace in the form of minute globules, each of which must be converted into vapor before it can burn. The heat required for this vaporization is derived from the highly heated firebrick with which the furnace is lined. Each globule of oil, on being converted into vapor, expands to many times its original volume, and this sudden increase of the volume of the oil makes it necessary to have a furnace that will accommodate the expansion. When the furnace is too small the expansion at the moment of vaporization increases the volume so greatly that the gases must travel very rapidly, and the result is that they pass out and come in contact with the boiler tubes or surfaces before the air has been thoroughly mixed with them and before combustion is complete.

The burner also affects the furnace efficiency; for the greater the size of the oil globules the longer will be the time required to convert them into vapor. Their expansion produces a pressure in the furnace, and this pressure, aided by the steam blast, quickly drives them on into the boiler passages. As a result, only the smallest globules are vaporized and burned in the furnace and the others are carried into the boiler passages, where their temperature is lowered and they are only partly burned. Even the carbon dioxide formed by combustion in the furnace may be converted to monoxide by taking up carbon from the unburned gases beyond the furnace.

If there is a very large percentage of carbon monoxide in the gases, secondary combustion may occur; that is, the monoxide may burn on its way through the passages of the boiler, or even in the uptake or the chimney. Although some heat may thus be recovered, the combustion takes place under poor conditions and is not nearly so efficient as when it takes place in the furnace. So, whether secondary combustion occurs or not, heat is lost.

The final effect of too small a furnace, therefore, is to give too rapid a travel of the gases through the furnace, with the subsequent formation of carbon monoxide and waste of heat. For these reasons the oil should be broken up into a spray almost too fine to be seen, and the furnace should have sufficient volume to allow combustion to be completed before the gases leave it. In this way the maximum temperature will be obtained and the loss due to carbon monoxide will be obviated.

The amount of air required for the complete combustion of a pound of oil fuel of known composition may be calculated approximately by the formula

$$W = 11.6\,C + 34.8\,H$$

in which

W = pounds of air per pound of oil;
C = percentage of carbon, expressed decimally;
H = percentage of hydrogen, expressed decimally.

For example, suppose that a certain grade of crude oil is found to contain 85 per cent. of carbon and 12 per cent. of hydrogen. The least amount of air that will burn a pound of this oil completely is

$$W = 11.6 \times 0.85 + 34.8 \times 0.12 = 14 \text{ lb., very nearly.}$$

Slight differences in the relative amounts of carbon and hydrogen in oils, together with the presence of such elements as oxygen, nitrogen and sulphur will cause the minimum amount of air per pound of oil to be greater or less than that just calculated; but with the oils ordinarily used as fuels in steam-boiler work, from 13 lb. to 14 lb. of air would be required per pound of oil if the combustion were ideal and complete.

Just as in the combustion of coal, so in the combustion of oil fuel it is necessary to admit an excess of air to the furnace. The reason is the same, namely, to insure a sufficient supply of oxygen to enable each particle of combustible matter to be burned completely. But there is a great difference between the excess required for solid fuel and that required for liquid fuel. The average coal-burning furnace seldom uses less than one and one-half times the minimum amount of air re-

quired for complete combustion, and usually it requires twice the amount or even more; that is, the excess of air ordinarily ranges from 50 per cent. to 100 per cent. and frequently exceeds the latter value. With oil fuel, the excess of air may be kept as low as 10 per cent. by efficient furnace arrangement and careful regulation, and it is not uncommon to find oil-burning plants in which the excess of air is not over 20 per cent.

The reason for the smaller supply of air required lies in the fact that the conditions in the oil-burning furnace are much more favorable to the thorough mixing of the air and the fuel than is the case in a coal-burning furnace. The oil is sprayed, and the air is admitted in such a way as to mingle intimately and uniformly with it. In the case of coal the air must pass up through the fuel bed, which is of varying thickness, with the result that the resistance is highest and the flow least where the supply should be greatest, that is, at the thickest part of the bed. The use of a small excess of air conduces to greater boiler efficiency because it results in a higher temperature of the products of combustion. For the heat generated is contained in a much smaller weight of gases than in the case of a coal fire.

The formation of soot or smoke is due to the presence of unburned carbon in the gases, and it may occur even when a sufficient amount of air is being admitted to the furnace. The point to be observed is that the combustible matter shall not only be surrounded with an ample supply of oxygen, but that the temperature of ignition shall be maintained until combustion is com-

plete. In the case of oil fuel the spray is first converted into gaseous hydrocarbons, and these hydrocarbons are broken up into free hydrogen and free carbon. If there is enough oxygen present and the temperature is sufficiently high, the hydrogen will burn to steam and the carbon to carbon dioxide; but if the temperature of the mixed gases is lowered by admitting an excessive amount of cold air, or by allowing the gases to impinge on cold boiler surfaces, combustion will be prevented and the unburned combustible will be carried along with the gases and go to waste.

The free unburned carbon is in the form of fine particles that, on cooling, assume the characteristic black color and appear as smoke or collect as soot on the boiler surfaces. This explains the use of firebrick linings and baffles in furnaces and combustion chambers in which oil is burned. The brickwork becomes incandescent and maintains the temperature necessary to insure the union of the carbon and the oxygen.

Although the condition of the fire in an oil-burning furnace can be judged by observing the flame and noting the roaring sound made by the burners, it is well if the fireman can keep an eye on the gases issuing from the top of the chimney. The smoke, if there is any, should be very light and uniform in color. If it becomes dense, it is a sign that the burners need to be regulated or the air supply readjusted.

Absence of smoke is not necessarily a sign of perfect combustion, and no fireman should assume that he is obtaining the best results in the furnace merely because there is no smoke issuing from the chimney; for

the supply of air may be greatly in excess of that required for economy. On this account it is wise to analyze the flue gases, or to install a continuous CO_2 recorder, so that the efficiency of combustion may be under the observation of the management. Particularly is this true of the plant that has been altered from the burning of coal to the burning of oil; for it is found that a fireman accustomed to fire coal is very apt to admit entirely too much air when he takes up the management of oil burners.

The idea that the admission of steam to the furnace increases the amount of heat generated is an error that is apparently based on a misunderstanding of the action of the steam during combustion. The steam that enters with the oil is heated to the temperature of the furnace, which is so high that the steam is decomposed, or broken up, into the elements hydrogen and oxygen. In the presence of the carbon and oxygen in the gases, however, the hydrogen and oxygen thus liberated are taken into combination again, forming steam and carbon dioxide. Moreover, the amount of heat resulting from the burning of the hydrogen is precisely equal to the amount that was required to set that hydrogen free during the decomposition of the steam. This is directly in compliance with the law of conservation of energy. The net gain, therefore, is nothing, and the final result is the same as though the steam had passed through the furnace without being decomposed. In other words, the steam not only does not add to the heat generated but actually carries away a part of the heat because it escapes to the chimney in a highly superheated condition.

CHAPTER XI

Management of Oil-burning Plants

The management of an oil-burning plant differs very considerably from the management of a coal-burning plant because of the rapidity with which any alteration in the rate of firing affects the generation of steam. With a coal fire the response to an increased rate of firing is slow, because it is necessary for the fresh fuel to become heated to the temperature of ignition before it can burn and give off heat. In the case of an oil fire, however, the combustion keeps pace with the rate of feeding the oil, so that an increased flow of oil is immediately followed by an increased generation of heat.

The fact that an oil-burning plant is so quickly responsive to alterations in the conditions of combustion makes it necessary to observe care in the regulation of the burners and the control of the air supply. It is particularly necessary to guard against the admission of too much air, which will dilute the products of combustion and cause loss of heat. A fireman accustomed to the use of solid fuel may find it difficult to learn to reduce the air supply sufficiently for the economic burning of oil, as oil requires a much smaller excess of air.

The method to be used in starting an oil fire under a boiler will depend on whether the boiler is the only one in the plant or whether there are other boilers already under steam. If steam is not available from

some auxiliary source, it is necessary to start an ordinary wood fire and get up steam pressure enough to atomize the oil. If the boiler is one that has been converted from coal burning to oil burning, and the grates are still in place, covered with firebrick, the wood fire is built right on the firebrick layer and is kept going until the steam gage on the boiler shows a pressure of at least 20 lb., which will be sufficient to atomize the oil for starting the fire. It is not necessary to remove the burner while this fire is under way, but the fire should be kept at a safe distance from the burner, so that the heat will not warp the tip or injure the pipes.

When the steam pressure reaches 20 lb. the oil-pressure pump should be started and the steam valve on the burner should be opened. Steam should be allowed to blow through the burner until the issuing jet appears to be dry. Then the oil valve is opened and oil is allowed to flow into the burner. The spray of oil will be directed into the wood fire on the floor of the furnace and will be ignited, after which the burner will continue its operation in the usual way. The wood fire may be allowed to burn out or it may be raked out after the oil fire has been started.

If there are other boilers in use, so that a supply of steam is at hand, the operation of starting an oil fire under a cold boiler is made much simpler and shorter. The first thing to do is to open the damper to its full extent. The steam and oil stop valves are kept closed, but the needle valve or oil-regulating valve is opened slightly. Now steam is admitted to the burner and is allowed to flow until the pipes and the burner are

heated and the issuing current seems to be dry, which indicates that there is no condensation collected in the steam-supply system. Next, a bunch of waste saturated with oil should be lighted and placed inside the furnace, on the firebrick, directly in the path of the steam blast. Then the fire-door should be closed quickly and the oil valve should be opened. The oil will flow through the partly opened needle valve or oil-regulating valve and the spray will be ignited by the burning waste. After the fire is thus started, the combustion may be regulated by adjusting the flow of oil and steam and by changing the air supply through manipulation of the ashpit doors and the damper.

Before starting the fire, it is a wise precaution to blow steam through the oil side of the burner to make sure that the oil passages are clear. This is done by opening the by-pass valve and the steam valve. After the fire is started the intensity of the fire should not be increased too rapidly, as there is danger in forcing the fires under a cold boiler.

The condition of the fire is observed through peepholes that are placed in front of the setting or at the sides. When the boiler and its setting have become heated to the usual working temperature the interior of the furnace should appear to be filled with flame, the color of which should verge on a dazzling white. The flame should be steady and not surging or gusty. An experienced fireman can judge the condition of his fire very accurately by observing the color of the flame, but it is advantageous if he can also see the top of the chimney.

The combustion of oil is accompanied by a roaring noise, and the nature of this roaring also serves as a guide to the conditions existing in the furnace. It is noticeable that an excessive supply of cold air greatly increases the noise, and that preheating of the air supply renders the combustion much quieter. It is natural to suppose, therefore, that the reduction of roaring in the furnace is accompanied by an increased efficiency of combustion, since it is obtained by cutting down the excess of air and by increasing its temperature.

The formation of smoke may be traced to an insufficient supply of air, an oversupply of oil or too little steam to atomize the oil thoroughly. A burner that has not been properly cleaned and that is clogged or imperfectly adjusted will produce an unsteady flame and may cause smoke. If there are scintillating particles in the flame and they appear to fall to the floor of the furnace, it may be concluded that the atomization is imperfect. The pressure of the atomizing agent should therefore be increased. If there is water in the oil or in the steam, the burner will spit and act erratically. A similar sputtering may be caused by the presence of gases in the oil, due to an excessive heating of the oil on its way to the burner.

In the average small plant using liquid fuel the burners are regulated by hand to accommodate the rate of firing to the demand for steam. This can be done readily because the number of burners to be adjusted is not great; but in a very large plant this method of control would be irksome, particularly if the load were subject to wide and frequent changes. With hand regula-

tion of the separate burners the economy depends on the intelligence of the fireman in judging the conditions of combustion and in the quickness with which he adjusts the burners to changes of load.

Automatic regulation is employed in some of the larger plants. The means by which regulation is effected varies, but the end attained is the same, namely, an increase or decrease in the rate of firing to correspond to an increase or decrease of load. An increased demand for steam is evidenced by a decrease of steam pressure in a boiler. One system of automatic control therefore uses a regulating valve on the oil line to the burners. This valve determines the rate of flow of the oil, and its stem is attached to a spring and to a diaphragm that is acted on by the steam pressure. The pressure of the spring and the steam pressure act to oppose each other, and the tension of the spring can be altered to suit conditions. By setting this spring to the proper tension, any decrease of steam pressure following an increased load on the boiler will allow the spring to open the valve slightly and more oil will be admitted to the burners. In this way the rate of combustion can be made to follow the demand for steam very closely. In this system the pressure of the oil as supplied by the pump remains constant.

In another system of automatic regulation the regulating valve takes the form of a pump governor. When an increase of load comes on, the governor admits more steam to the pump, which increases its speed and gives a higher oil pressure. The oil valves at the burners are left open, and the result of the higher pressure is an

increased flow of oil. There is a greater amount of heat thus generated and the steam pressure is quickly brought back to normal by the accelerated evaporation. While the steam pressure is increasing the governor is gradually cutting down the speed of the pump. In this way the steam pressure is kept fairly uniform.

Of course, an increased flow of oil demands an increased flow of steam to atomize it properly. In the system of control just described the steam supply is regulated by a valve whose stem is fastened to a diaphragm acted on by the oil pressure. An increased oil pressure immediately causes an increased opening of the steam valve, and thus the correct ratio of steam to oil is maintained.

The draft required for the burning of oil fuel is very small, ranging from about 1/8 in. to 1/2 in. of water. This is much less than is required for the burning of solid fuels and is accounted for by the fact that in an oil-burning boiler the only resistance to be overcome by the draft is that due to the friction of the gases in passing through the furnace, among or through the tubes and along the breeching and the chimney to the outer air. In a coal-burning boiler the draft must not only overcome these resistances but must also cause the air supply to rise through the bed of fuel on the grates. For this reason the chimney of a coal-burning plant will give too strong a draft when the fuel is changed to oil, and to prevent the inrush of too much air the damper must be closed to a greater extent than when solid fuel is used.

The regulation of the air supply to the furnace may

be effected either by means of the damper alone or by means of the damper and the ashpit doors. When the damper alone is used, the ashpit doors are left wide open and the rate at which air flows into the furnace is controlled by the amount of opening of the damper. The advantage of this system of control is that at all times there is ample opening for the admission of air and the air enters at a rate sufficient to replace the gases that escape to the chimney. By impeding the escape of hot gases at the damper the hot products of combustion are kept in contact with the boiler surfaces for a longer period and the rate of travel is reduced, thus giving ample time for complete combustion.

It is probable, however, that in the larger number of plants the regulation is accomplished by both the damper and the ashpit doors. When the load on the boiler decreases the amounts of air and oil are reduced. This results in a corresponding reduction of the weight of gases formed in the furnace, and so the damper should be moved toward its closed position. When the demand for steam increases the opposite adjustment must be made. In any case, the object to be attained is efficient combustion, and this should be done with the least possible amount of air. To judge as to when this point has been reached, the air supply may be cut down until smoke is formed, indicating that there is too little air. Then the supply may be increased gradually until the smoke disappears and only a slight haze is visible at the top of the chimney.

When an oil-burning boiler is to be shut down, the stop valve on the oil line to the burners should be

closed first of all, thus cutting off the flow of oil and stopping combustion in the furnace. Next, the steam valve should be closed until only a small jet of steam escapes from the burner. The oil side of the burner should then be blown out, which is done by opening the oil-regulating valve on the burner, the by-pass valve and then the steam valve. This precaution is necessary to prevent clogging of the burner; for if the oil is allowed to remain stagnant in the burner and its connecting pipes, the heat of the setting will carbonize the oil and bake its tarry constituents on the inside of the passages, and there will be trouble and delay when the burner is again put into service. The ashpit doors and any other openings for the admission of cold air to the furnace should be closed and the damper opened, so that the setting may not cool too rapidly.

As a usual thing, the heat stored in the brick lining of the furnace will reignite the oil spray if the flow of oil is interrupted for a few seconds. If the supply of oil is cut off for some time, however, the temperature of the furnace may fall to such a point that the oil cannot be ignited by the heat of the firebrick. In such a case the fireman should shut off all oil and then close the steam valve, putting the burners out of action. Then he should throw a bunch of burning waste into the furnace, close the fire-door and restart the burner in the usual way.

The inflammable nature of oil fuel renders accidental fires a possibility. Should oil escape from the pipes and become ignited, the flames should be smothered by scattering sand or earth over the surface of the blazing

liquid. The air is thus shut off from the oil and combustion dies out because of the lack of oxygen. It is useless to attempt to put out an oil fire by turning water on it, because the only effect of the water will be to spread the oil without extinguishing the flame.

CHAPTER XII

Purchase of Oil Fuel

When it comes to the purchase of oil fuel, the buyer is interested in obtaining the greatest possible heat value for the money expended; therefore, he wishes to know the amounts of water, sulphur and sediment in the oil, the heat value, the flash point and the specific gravity. From a knowledge of these properties he can determine how well the oil is suited to his purposes.

The Bureau of Mines has issued a pamphlet detailing the specifications for oil purchased by the United States government and describing methods of sampling. The following information concerning the requirements of oil for fuel purposes and the methods of obtaining samples is taken largely from this publication.

The oil available for fuel may be either crude oil or fuel oil. In the first case it is simply natural petroleum as it comes from the well, and in the latter case it is the residue left after the lighter and more volatile constituents of crude oil have been driven off. In either case the oil should be homogeneous, or of uniform composition throughout. It should not be a mixture of light and heavy oils in such proportions as to give the desired specific gravity.

If it is a fuel oil—that is, has been subjected to a preliminary heat treatment—the temperature to which

it was heated should not have been so high as to burn it, nor should the temperature have been so high as to cause the separation of carbon, which would afterward appear as flecks in the oil.

To be quite safe the oil should have a flash point of not less than 140 deg. Fahr., and this point should be determined by means of a closed tester. The flash point of an oil is the temperature at which the oil will give off vapors that will ignite when a naked flame is brought in contact with them. A crude form of test for the flash point may be made by putting a sample of oil in a cup, placing the cup in an iron vessel containing sand and applying heat to the sand so as to increase the temperature of the oil gradually. At short intervals during the heating the flame of a match is passed over the surface of the oil and about 1/2 in. from it. Eventually a point will be reached when the gases rising from the heated oil will ignite and burn with a blue flash when the match is applied. The temperature of the oil when this action is first noticed is called the flash point.

The open cup, though forming a simple means of finding the flash point, is not accurate, because there is too much opportunity for variation in the conditions under which the test is conducted. It is very difficult to screen an open cup from all drafts and air currents, and if these are not prevented the gases rising from the oil will be diffused more or less quickly and the results will not be correct. The quantity of air in the top of the cup, just above the surface of the oil, influences the flash point. The rate at which the oil is heated will affect the result. The more rapid the heating, the more

rapid the formation of gases and the lower is the flash point.

The quantity of oil also has a bearing on the result obtained. The greater the quantity of oil, the greater is the quantity of gases driven off and the lower the flash point. The form and size of the oil cup are controlling factors. The evaporation is most rapid with a large, shallow cup, and the flash point with such a cup is lower. The most nearly uniform results are to be obtained with a cup that is fairly deep in comparison with its diameter and that is filled about half full.

The flame by which the test is applied should be of constant size and shape if uniform results are desired, and the time during which it acts should always be the same. Again, its distance from the surface of the oil at the instant the test is made should not vary. The larger the flame or the closer it is brought to the surface of the oil, the lower is the flash point. It is best to pass the flame across the center of the cup, from one edge to the other, because the mixture of gas and air is most complete at the edge of the cup.

To obtain accuracy of results and to allow the results to be compared, flash tests should be made in a closed tester, such as the Abel tester, shown in section in Fig. 60. It consists of a cup *a*, about 2 in. in diameter and 2 1/4 in. deep, into which the oil to be tested is poured, always to the same level, as indicated by the tip of a bent wire *b* soldered to the inside of the cup. The cover of the cup carries a thermometer *c* for registering the temperature of the oil. It also carries a slide *d* to which is swiveled a lamp *e* by which the flash test is

made. The arrangement of the lamp on the cover of the cup is clearly shown in Fig. 61. The body of the

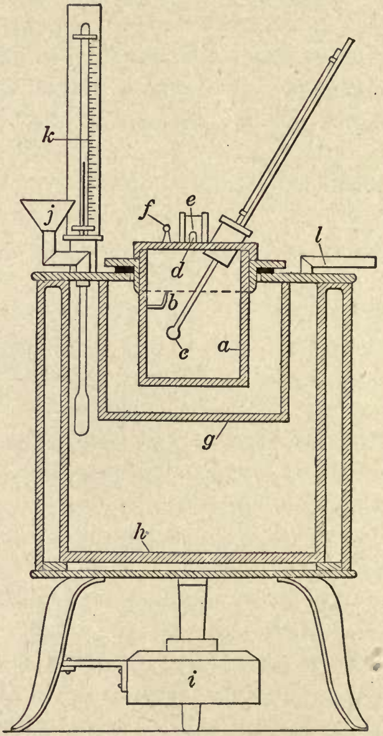


FIG. 60.—Section of oil tester.

lamp is filled with colza oil or rape oil, and at the end of the spout is a wick. In the slide is a rectangular slot, and under the slide are three slots in the cover of

the cup; thus, when the slide is drawn across the cover, its slot registers with the slots in the cover. A pin projects from the slide, and when the latter is pulled out the pin tilts the narrow spout of the lamp down into the slot and thus brings the flame in contact with the gases in the cup. There is a white bead *f*, Fig. 60, fixed to the cover just opposite the flame of the test lamp, and the size of this bead is a guide to the size of the test flame to be used.

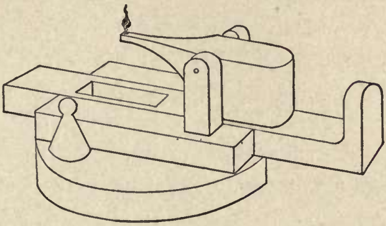


FIG. 61.—Lamp of tester for flash point of oil.

The oil to be tested is heated by a water bath contained in the copper vessels *g* and *h*. Heat is applied by the spirit lamp *i*. The water for the bath is poured into the funnel *j*, its temperature is indicated by the thermometer *k*, and the excess escapes at the overflow *l*.

To make a test, the apparatus is placed in a fairly dark place, so that the size of the test flame can easily be compared with the bead *f*; also, the flame is shielded from all air currents. The water bath is filled with water at a temperature of 130 deg. Fahr., and the oil to be tested is poured into the cup to the level of the gage wire *b*. The thermometer *c* is next inserted and

the spirit lamp *i* is lighted. When the oil reaches a temperature of 66 deg. Fahr., the test flame is applied for the first time, and again after that every time the temperature of the oil has increased one degree.

To insure absolute uniformity, the test flame is applied according to the swinging of a pendulum 24 in. long, which is set up near the operator. The slide *d* is slowly drawn out while the pendulum is making three full swings in both directions and is pushed back to its original position during the fourth swing. When the vapor rising from the oil is ignited by the lamp and gives a momentary flash of blue flame, the temperature registered by the thermometer *c* should be noted. This reading is the flash point of the oil. The firing point may be determined next, if desired. It is the temperature at which the gases are given off in such quantity that they burn continuously when ignited by the test flame.

If the oil contains water, the sample to be used for the flash test should be freed from water before being put into the tester; for as little as 1 per cent. of water in oil will cause the flame to be extinguished when making a flash test.

One method of determining the percentage of water in oil is to make use of the affinity of petroleum ether for water. A weighed sample of the oil to be tested is placed in a test tube, petroleum ether is added, the two are shaken together and are then allowed to stand. The ether, with the water it has taken up from the oil, will collect on top of the oil and should be decanted into another tube. The remaining oil should again be

washed with petroleum ether, the clear solution decanted and added to that in the second tube. A third washing may be performed in the same way.

The water in the oil is removed by these washings, being carried away by the ether. The second test tube is now heated to a temperature of from 100 deg. to 140 deg. Fahr., when the petroleum ether boils and passes off, leaving the water in the bottom of the test tube. The weight of this water, divided by the weight of the original sample of oil and multiplied by 100, gives the percentage of water in the oil.

Another method is to weigh the sample of oil and then to add to it a known weight of plaster of Paris that has been gently ignited. The plaster of Paris will take up all the water in the oil, after which it should be removed and washed with gasoline to remove all oil. It should then be dried at a gentle heat, to drive off the remaining gasoline, and weighed. The increase of weight represents the water absorbed from the oil. Thus, the weight of the original sample of oil and the weight of the moisture are known, and the percentage of moisture may readily be calculated. A good oil for fuel should not contain more than 2 per cent. of water.

Oil should have a specific gravity of from 0.85 to 0.96 at a temperature of 59 deg. Fahr., and should be rejected if its specific gravity is 0.97 or more at that temperature. It should not contain any solid or semi-solid bodies and should flow readily at ordinary temperatures. A good test for fluidity is that the oil shall flow easily through 10 ft. of 4-in. pipe under the pressure due to a head of 1 ft. of oil. It should not freeze

or become too sluggish to flow at 32 deg. Fahr. The calorific value should not be less than 18,000 British thermal units per pound. As to cleanness there should be no more than a trace of sand, dirt or clay.

The oil should not contain more than 1 per cent. of sulphur. The amount present in the oil may be determined in the following manner: A sample of 50 cc. is put in a flask and 0.5 gram of sodium bicarbonate is added. Heat is applied to the mixture and it is distilled at the rate of about 50 drops per minute until about 45 cc. has been driven off. The residue is then placed in a large porcelain dish and is washed several times with petroleum ether. The ether is collected from the several washings and evaporated. About half a gram of sodium is next added in small pieces, the whole is evaporated over a small flame until it becomes sirupy, and then is ignited. The ignition is continued until the ash is quite white, ammonium nitrate being added gradually during the operation. The residue is treated with very dilute hydrochloric acid and barium chloride is added, precipitating barium sulphate. The precipitate is separated by filtration, washed, ignited, and weighed, and the amount of sulphur contained in it is calculated by multiplying its weight by 0.13733. The weight of sulphur divided by the weight of the original sample and multiplied by 100 gives the percentage of sulphur in the oil.

A test may be made with the greatest degree of accuracy, yet it will be of little value in showing the composition of an oil unless the sample that is tested represents properly the whole quantity of oil. Poor methods

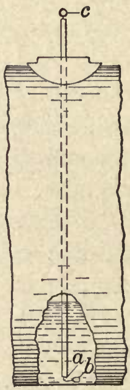
of taking samples or mistakes in following approved methods may result in unfair and misleading results. For this reason it is very important that the sampling be done correctly.

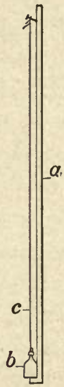
The manner in which samples are taken depends on the way in which the fuel is delivered. If the oil is brought by tank wagon or tank car and is allowed to flow into the storage tank in such a way that the end of the discharge pipe is accessible, sampling may be done with a dipper holding about a pint. Immediately after the oil begins to flow into the storage tank, the dipper should be filled from the stream of oil escaping at the end of the pipe. The sample thus obtained should be poured into a clean vessel. In the same way other samples should be taken at equal spaces of time during the emptying of the car or wagon. The samples should be taken often enough to give a final combined sample of at least a gallon, and this gallon sample should be thoroughly mixed before any of it is tested for water or sulphur. The dipper used for taking the samples should always be filled to the same point, so that equal amounts will be taken at equal intervals; but if the first dipperful shows water in the oil, it should be thrown away and not poured into the receiving vessel.

In case the end of the discharge pipe cannot be reached for sampling with a dipper, a hole may be tapped in the under side of the pipe and a short piece of 1/2-in. pipe and a valve attached. Then, during the whole time in which the oil is being discharged, the valve should be left open a fixed amount and a continuous sample of the oil thus collected. This quantity

should be thoroughly mixed in a clean vessel and a sample of about a gallon should be taken from it for the tests.

In case the oil is to be sampled in a tank, a piece of 1-in. pipe somewhat longer than the depth of the tank should be used, as shown in Fig. 62. A piece of wire *a* is attached to a tapered wooden plug *b* of sufficient size to close the end of the pipe. The wire is carried through the pipe and has a loop *c* at the upper end. To take





FIGS. 62 and 63.—Sampling pipe and sampling bottle on rod.

the sample, the pipe with the plug hanging below it is slowly lowered vertically into the oil. As it descends the oil rises inside it, and when it has reached the bottom it has inclosed a column of oil from the top to the bottom. The wire is now pulled up, drawing the plug into the lower end of the pipe, where it may be fixed securely by bumping the pipe against the bottom of the tank.

The pipe is now drawn out and emptied into a vessel. The oil thus obtained is a representative sample, because it contains oil from every level between the top and the bottom of the tank; thus, even if the oil has separated into layers of different specific gravities, the sample includes some of each. Particular care should be taken to lower the pipe slowly, so that the oil will not be stirred up.

If it is deemed advisable to take samples from various parts of a tank instead of just below the manhole, a device like that in Fig. 63 may be used to advantage. It consists of a pole *a*, long enough to reach to any part of the tank, to which is fixed a bottle *b*. To the cork is fastened a string *c* whose other end is attached to the upper end of the pole. To use the sampler, the bottle is cleaned and loosely corked. Then it is lowered by the pole to the point where the sample is to be taken and the cork is removed by a pull on the string. The bottle immediately fills with oil, is drawn out, emptied, and cleaned for the next sampling. In this way samples are taken from various points symmetrically located in the tank. These samples, when mixed thoroughly, form a representative sample.

Sand or earthy matter in oil will eventually settle to the bottom if the oil is allowed to stand for a time undisturbed. Consequently, to determine whether an oil contains dirt, a cup fixed to a long handle may be used to scrape up a sample along the bottom of the tank. If the cupful shows a considerable amount of solid matter, the oil is dirty and may prove troublesome to use.

There has been considerable speculation as to what

effect would be produced on the tubes and plates of steam boilers by the use of oil fuel containing a large percentage of sulphur. The oil-trade publication *Petroleum*, in a brief article relating specifically to Spindle Top oil, derived from the Beaumont field, Texas, states that the results in many tests have shown that "iron or steel flues and plates are not more seriously affected than by the ordinary coal fuel. Sulphur, existing in a free state, or as sulphuretted hydrogen in the combustion chamber, has both hydrogen and oxygen presented to it, with which it will unite in preference and will not act corrosively on the metal of the boiler. It is besides greatly adulterated by the volume of nitrogen, oxygen and hydrogen. In many of the best grades of bituminous coal, the sulphur varies from 1 per cent. in the best to 3 1/2 per cent. Even coal containing as much as 4 to 5 per cent. of sulphur is used without injury to the boiler proper, however much the grate bars may suffer. The percentage of sulphur—actually not more than 1.33 per cent.—is lower than that found in some descriptions of coal used as fuel, and cannot be regarded as disqualifying the oil for advantageous employment in the furnaces of steam boilers."

Aston

CHAPTER XIII

Advantages and Disadvantages of Oil Fuel

Oil as a fuel has several well-defined advantages over coal and other solid fuels. Perhaps the most apparent of these is the ease and rapidity with which the rate of firing may be changed. In a plant in which regulation is carried out by hand, the simple operation of turning a valve or a cock suffices to increase or decrease the flow of oil to the burners, whereas if automatic regulation is used the ratio of steam to oil and of oil to load are all taken care of by the automatic devices. The result of this action is that the rate of combustion follows the load so closely that the steam pressure can be kept very nearly uniform. In addition to this feature, it is possible to extinguish the fires almost instantly, in case of accident to some part of the plant, and thus prevent further disaster.

Inasmuch as the rate of firing can be increased from almost nothing to the maximum in the short space of time required to open a valve, the response to a sudden increase of load on the boiler is much quicker with oil fuel than with coal. For with coal firing, an increase of load is met by throwing greater quantities of fuel on the grates, the immediate result of which is to chill the fire and reduce the amount of heat liberated. After the fresh fuel has become heated and ignited it

gives off increased heat, but this requires appreciable time. With oil, the generation of heat is proportional to the amount of oil fed and is simultaneous with the injection of the oil into the furnace. The advantage of this in a plant that is subject to frequent and wide variations in load must be apparent.

In the hands of an ignorant and untrained fireman, however, this ease of control may prove to be a source of trouble and danger. For, in getting up steam from a cold boiler or in bringing a banked boiler into normal working condition he may force the firing to such an extent as to burn the plates or tubes and render the boiler unsafe.

An increase of steaming capacity is made possible by a change from solid to liquid fuel, provided, of course, that reasonable precautions are taken to arrange the furnace for the economical use of oil. The increase of capacity is attributable to a number of causes. In the first place, oil has a greater calorific value per pound than coal. A pound of high-grade steam coal will yield 13,500 British thermal units and a pound of oil of average quality will contain 18,600 British thermal units. The difference, 5,100 British thermal units, represents 38 per cent. of the heating value of the coal; therefore, it may safely be stated that oil has from 30 to 35 per cent. greater calorific value than coal.

When burned in the furnace, a greater percentage of the heating value of the oil is utilized than in the case of coal. In the first place, a smaller excess of air is required for oil, because the mixing with the fuel is more thorough. The combustion is therefore more

efficient, a greater percentage of the available heat is developed, and the temperature of the furnace is higher than with coal because the weight of gases produced by combustion is smaller. As a consequence, these gases give up more heat to the boiler than do the products of combustion of coal.

The heating surfaces of a properly managed oil-burning boiler are cleaner than those of a coal-burning boiler because the improved furnace conditions lessen the formation of soot, and there are no solid particles to be carried into the tubes by the draft. This renders the transfer of heat from the gases to the water more rapid and raises the evaporative efficiency. Again, with oil fuel there is no necessity for opening the fire-doors at frequent intervals, as is done in the hand firing of coal; therefore, the furnace conditions are kept more nearly uniform, there is a better distribution of the heat generated, and the stresses due to the cooling effect of large volumes of cold air admitted to the furnace are avoided.

There are just two fundamental ways of increasing the efficiency of a boiler, and they are to increase the amount of heat absorbed and to reduce the amount of heat thrown away. With oil as a fuel, less heat is used to raise the temperature of the excess air and more heat is transferred to the water. The net result of these two actions is that a smaller percentage of heat escapes up the chimney in the gases, and so the efficiency is increased.

Because of the slight excess of air that is required in an oil-burning installation the weight of gases formed

per pound of oil is less than the weight resulting from the combustion of a pound of coal, and a chimney of smaller capacity can be used. Again, the draft needed for oil fuel is from one-tenth to one-half that necessary for the efficient burning of coal; consequently, the height of the chimney need not be so great when oil is used. In the case of a plant converted from coal burning to oil burning, the existing chimney would be used without alteration, and this particular advantage would be of no immediate benefit; but in the case of a new plant designed for oil fuel the cost of chimney construction would be considerably less than for a coal-burning plant of equal capacity, because of the reduced height and diameter of the chimney.

Another striking advantage of oil as a fuel is the lessening of manual labor by its use. Instead of transporting the fuel from the storage bins in trucks or barrows and feeding it to the furnaces with scoops, as in the case of coal, the oil is drawn from the storage tanks and sent to the burners by steam pumps. As a consequence, the number of firemen may be reduced to one-half or even one-fifth of the original number, depending on the size of the plant and its arrangement. Even a coal-burning plant equipped with conveyors and other mechanical devices requires far more power for handling the fuel than does an oil-burning plant of equal capacity. Moreover, oil can be pumped through pipes to far greater distances and at much smaller expense than would be possible in the case of coal. For example, take the case of a plant situated near a river or other deep waterway, to which fuel could be brought

by barges or steamers. If coal were used, expensive machinery would be required to transfer it from the barges to the plant over the intervening distance; but if oil were the fuel, all that would be required would be a pipe line between the plant and the edge of the river, as compared with the structural work required to carry the coal-handling machinery.

In the matter of storage space required, oil has a vast advantage over coal. Oil possesses about one-third more heating value than an equal weight of coal and a pound of oil occupies about three-fifths of the space required for a pound of coal; therefore, the heating value of the oil that can be stored in a given space is almost 50 per cent. greater than that of the coal that could be put in the same space. To put it in another way, the storage space required when oil is used as a fuel is only about two-thirds of that for coal, assuming the same boiler horsepower in both cases.

The ashes produced in the burning of coal must be removed periodically. The handling of these ashes in the boiler room produces dust, and the whole process of removal involves expense. Oil produces no ashes and no dust, and, if properly burned, no soot. The result is that there is no expense for removal of ashes, the wear and tear on the pumps in the boiler room is reduced by the absence of dust, and the tubes and surfaces of the boiler remain clean for longer periods than when coal is used. This last condition lessens the frequency of cleaning the tubes and so reduces labor and expense.

The apparatus used in connection with oil burning is

simple and is not apt to get out of order; therefore, the cost of maintenance is not great. Burners may wear, owing to erosion by the oil and steam, or may warp under the effect of the intense heat so as to require renewal; but the absence of moving or sliding parts reduces the repair bills to a minimum. There are no grates to be replaced, and no firing tools are used, so that damage to the bridge wall or to the furnace lining through the careless use of tools is wholly avoided.

It is well known that coal, when stored for any length of time, deteriorates in heating value because of slow oxidation and the escape of hydrocarbons; but oil may be stored for long periods in properly ventilated tanks without losing appreciably in its heating value.

Again, there is the matter of smokelessness to be considered. By reason of the efficient combustion that may be obtained, oil can be burned without smoke; so that, in a city in which the production of smoke by manufacturing plants is punished by fines, the use of oil fuel may be the means of solving a trying problem.

One of the chief disadvantages attending the use of oil fuel is imposed by the regulations of insurance companies. To protect the plant from fire that might occur from the ignition of the inflammable oil, it is required that the storage tank shall be 30 ft. from the nearest building and 2 ft. below the surface of the ground, or 200 ft. from inflammable property if located above ground. It may be difficult to comply with these regulations if the ground surrounding a plant is in great demand or is already occupied.

Another disadvantage of oil is the inflammability of

the gases given off from it. The danger of explosion of these gases and the subsequent ignition of the oil, however, become of small importance if the oil used has a flash point of 140 deg. Fahr. or more, and if reasonable precautions are taken in storing and using it.

If the boiler feed-water contains a large percentage of scale-forming material, the use of oil fuel may entail increased expense for repairs and tube renewals; for the intense heat generated in an oil-burning furnace is apt to cause more rapid deposit of scale and result in a greater number of burned tubes and plates than with a coal fire.

CHAPTER XIV

PERFORMANCES OF OIL-BURNING BOILERS

The evaporation of a pound of water at 212 deg. Fahr. into steam at the same temperature requires 970.4 British thermal units; therefore, if all the heat in a pound of oil containing 18,600 British thermal units could be used in evaporating water, it would convert $18,600 \div 970.4 = 19.2$ lb. of water at 212 deg. Fahr. into steam. Under the same conditions, a pound of coal having a calorific value of 13,500 British thermal units would evaporate 13.9 lb. of water.

Such results as the foregoing, however, are not attainable in practice, because some of the heat in the fuel is spent otherwise than in heating the water in the boiler. For example, part of it escapes up the chimney in the flue gases, which leave the boiler at a temperature of 400 deg. Fahr. or more, and some of it is lost by radiation. The result is that only a part of the heat content of the fuel is usefully employed in converting water into steam. The ratio of the heat actually used in evaporating water to the amount supplied to the furnace in the fuel in the same time is the net boiler efficiency.

The boiler efficiency varies considerably, even in the case of boilers of the same size and make, and in the case of the same boiler operated under different conditions. It depends on such factors as the quality of combustion,

TABLE V.—RESULTS OF TESTS ON OIL-BURNING BOILERS

Designation of tests	A	B	C
Duration of test, hr	7	8	4
Steam pressure, lb	184.8	178.5	142
Superheat, deg. Fahr	98.3	160	83
Feed-water temperature, deg. Fahr	93.7	165	119.6
Barometer, in. of mercury	29.97	30.4	......
Boiler-room temperature, deg. Fahr	86.2	75	82
Flue-gas temperature, deg. Fahr	434.5	384	488
Draft in ashpit, in	0.084	0.02	......
Draft in furnace, in	0.062	....	0.15
Carbon dioxide, per cent	13.2	13.05	13.25
Oxygen, per cent	3.1	....	5.15
Excess of air, per cent	21.2	18	......
Total water evaporated, lb	147,351	156,974	82,317
Evap. from and at 212 deg. Fahr., lb	182,771	186,799	97,694
Steam used by burners, lb. per hr	568	....	377
Steam used by burners, per cent. of total	2.15	....	1.54
Steam pressure to burners, lb	122.2	....	......
Oil pressure to burners, lb	31.6	78	......
Oil temperature at burners, deg. Fahr	137.9	128	97
Specific gravity of oil at 60 deg. Fahr	0.9776	0.9700	......
Moisture in oil, per cent	0.54	1.2	......
Heat value of oil as fired, B.T.U	18,184	....	17,425
Heat value of oil, corrected, B.T.U	18,281	18,513	......
Oil fired per hr., lb	1,745	1,480	1,672
Oil fired per hr., corrected, lb	1,735	1,462	......
Evap. per sq. ft. of heating surface, lb	4.32	3.62	3.60
Rated horsepower of boiler	604	645	595
Boiler horsepower developed	756.8	676.7	707.9
Evaporation from and at 212 deg. Fahr. per lb. of oil, as fired, lb.	15.15	15.775	14.61
Evaporation from and at 212 deg. Fahr. per lb. of oil, corrected, lb.	15.23	15.967	.
Boiler efficiency, per cent	80.47	83.69	80.97

eakage of air into the furnace or passages, loss of heat, and direct loss of fuel. In a coal-burning boiler, the efficiency will not exceed 75 per cent. very often. If it is between 70 and 75 per cent., the performance may be considered very satisfactory; but if it falls below 60 per cent., efforts should be made to determine the source of loss and remedy the defect.

In the case of boilers using oil fuel, a much higher boiler efficiency may be expected, because of the increased efficiency of combustion. There are records of numerous tests showing efficiencies of more than 80 per cent., and at least one test came to within a very small fraction of 84 per cent. In fact, if the efficiency of an oil-burning boiler falls below 75 per cent., an examination should be made to discover the cause of the lowered efficiency.

Data on the performances of steam boilers burning oil fuel are given in Table V. The values given in the column headed A represent the average of seven tests made in 1907 on a Babcock & Wilcox boiler with Hammel burners. Several features of the tests may be pointed out as contributing to the excellent economy secured. The temperature of the escaping flue gases was reduced to 434.5 deg. Fahr., the amount of carbon dioxide in the flue gases was 13.2 per cent., and the excess of air amounted to only 21.2 per cent. The oil used was a crude oil from the Los Angeles field, and the ashpit doors were left wide open during the tests, the draft being regulated by the damper.

The results shown in column B were obtained in 1911 from a single test of a Parker boiler fitted with a tubular inside-mixing slot burner. The extremely high efficiency

of 83.69 per cent. may be attributed to excellent combustion and a low flue-gas temperature.

These same features stand out prominently in the data shown in column C, which were obtained in 1907 from a single test of a Babcock & Wilcox boiler with a Peabody furnace and a Peabody burner directed toward the front of the boiler. The small amount of steam used by the burners—1.54 per cent. of the total steam generated—is an excellent showing.

These three sets of data show unusually good performances, but they likewise indicate the results that can be obtained by the careful operation of oil-burning equipment well designed and arranged.

INDEX

(Numbers refer to pages)